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MONITORING AND EVALUATION OF SMOLT MIGRATION IN THE COLUMBIA BASIN VOLUME V

Evaluation of the 1999 Predictions of the Run-Timing of Wild Migrant Yearling and Subyearling Chinook Salmon & Steelhead Trout, & Hatchery Sockeye Salmon in the Snake River Basin using Program RealTime

Technical Report 2000

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MONITORING AND EVALUATION OF SMOLT MIGRATION IN THE COLUMBIA BASIN

VOLUME V

Evaluation of the 1999 Predictions of the Run-Timing of Wild Migrant Yearling and Subyearling Chinook Salmon and Steelhead Trout, and Hatchery Sockeye Salmon in the Snake River Basin using Program RealTime

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July 2000

Monitoring and Evaluation of Smolt Migration in the Columbia Basin

Other Publications in this Series

Volume I: Townsend, R. L., J. R. Skalski, and D. Yasuda. 1997. Evaluation of the 1995 predictions of run-timing of wild migrant subyearling chinook in the Snake River Basin using program RealTime. Technical Report (DOE/BP-35885-11) to BPA, Project 91-051-00, Contract 91-BI-91572.

Volume II: Townsend, R. L., J. R. Skalski, and D. Yasuda. 1998. Evaluation of the 1996 predictions of run-timing of wild migrant subyearling chinook in the Snake River Basin using program RealTime. Technical Report (DOE/BP-91572-2) to BPA, Project 91-051-00, Contract 91-BI-91572.

Volume III: Townsend, R. L., J. R. Skalski, and D. Yasuda. 2000. Evaluation of the 1997 predictions of run-timing of wild migrant yearling and subyearling chinook and sockye in the Snake River Basin using program RealTime. Technical Report (accepted) to BPA, Project 91-051-00, Contract 91-BI-91572.

Volume IV: Burgess,C., R. L. Townsend, J..R. Skalski, and D. Yasuda. 2000. Evaluation of the 1998 predictions of the run-timing of wild migrant yearling and subyearling chinook and steelhead, and hatchery sockeye in the Snake River Basin using program RealTime. Technical Report (submitted) to BPA, Project 91-051-00, Contract 96BI-91572.

Other Publications Related to this Series

Other related publications, reports and papers available through the professional literature or from the Bonneville Power Administration (BPA) Public Information Center - CKPS-1, P.O. Box 3621, Portland, OR 97208.

1997

Townsend, R. L., D. Yasuda, and J. R. Skalski. 1997. Evaluation of the 1996 predictions of run timing of wild migrant spring/summer yearling chinook in the Snake River Basin using program RealTime. Technical Report (DOE/BP-91572-1) to BPA, Project 91-051-00, Contract 91-BI-91572.

1996

Townsend, R. L., P. Westhagen, D. Yasuda, J. R. Skalski, and K. Ryding. 1996. Evaluation of the 1995 predictions of run timing of wild migrant spring/summer yearling chinook in the Snake River Basin using program RealTime. Technical Report (DOE/BP-35885-9) to BPA, Project 91-051-00, Contract 87-BI-35885.

1995

Townsend, R. L., P. Westhagen, D. Yasuda, and J. R. Skalski. 1995. Evaluation of the 1994 predictions of the run-timing of wild migrant yearling chinook in the Snake River

Basin. Technical Report (DOE/BP-35885-8) to BPA, Project 91-051-00, Contract 87-BI-35885.

1994

Skalski, J. R., G. Tartakovsky, S. G. Smith, P. Westhagen, and A. E. Giorgi. 1994. Pre-1994 season projection of run-timing capabilities using PIT-tag databases. Technical Report (DOE/BP-35885-7) to BPA, Project 91-051-00, Contract 87-BI-35885.

1993

Skalski, J. R., and A. E. Giorgi. 1993. A plan for estimating smolt travel time and survival in the Snake and Columbia Rivers. Technical Report (DOE/BP-35885-3) to BPA, Project 91-051-00, Contract 87-BI-35885.

Smith, S. G., J. R. Skalski, and A. E. Giorgi. 1993. Statistical evaluation of travel time estimation based on data from freeze-branded chinook salmon on the Snake River, 1982-1990. Technical Report (DOE/BP-35885-4) to BPA, Project 91-051-00, Contract 87-BI-35885.

Preface

Project 91-051 was initiated in response to the Endangered Species Act (ESA) and the subsequent 1994 Council Fish and Wildlife Program (FWP) call for regional analytical methods for monitoring and evaluation. This project supports the need to have the "best available" scientific information accessible to the BPA, fisheries community, decision-makers, and public by analyzing historical tagging data to investigate smolt outmigration dynamics, salmonid life histories and productivity, and providing real-time analysis to monitor outmigration timing for use in water management and fish operations of the hydrosystem. Primary objectives and management implications of this project include: (1) to address the need for further synthesis of historical tagging and other biological information to improve understanding and identify future research and analysis needs; (2) to assist in the development of improved monitoring capabilities, statistical methodologies and software tools to aid management in optimizing operational and fish passage strategies to maximize the protection and survival of listed threatened and endangered Snake River salmon populations and other listed and nonlisted stocks in the Columbia River Basin; (3) to design better analysis tools for evaluation programs; and (4) to provide statistical support to the Bonneville Power Administration and the Northwest fisheries community.

The following report addresses measure 4.3C of the 1994 Northwest Power Planning Council's Fish and Wildlife Program with emphasis on improved monitoring and evaluation of smolt migration in the Columbia River Basin. This report represents the ninth in a series of technical report presenting results of applications of statistical program RealTime to present in-season predictions of the status of smolt migrations in the Columbia River Basin. Results are presented from using program RealTime to predict the 1999 in-season migration status and trend of the spring/summer-outmigration of wild yearling chinook and wild steelhead and hatchery age 1+ sockeye from Redfish Lake, and the summer-outmigration of wild subyearling chinook at Lower Granite Dam. It is hoped that making these real-time predictions and supporting data available on the Internet for use by the Technical Management Team (TMT) and members of the fisheries community will contribute to effective in-season population monitoring and assist in-season management of river and fisheries resources. Having the capability to more accurately predict smolt outmigration status improves the ability to match flow augmentation to the migration timing of

ESA listed and other salmonid stocks and also contributes to the regional goal of increasing juvenile passage survival through the Columbia River system.

ABSTRACT

Program RealTime provided tracking and forecasting of the 1999 inseason outmigration via the internet for stocks of wild PIT-tagged spring/summer chinook salmon. These stocks were ESUs from sixteen release sites above Lower Granite dam, including Bear Valley Creek, Big Creek, Cape Horn Creek, Catherine Creek, Elk Creek, Herd Creek, Imnaha River, Lake Creek, Loon Creek, Lostine River, Marsh Creek, Minam River, South Fork Salmon River, and Secesh River, Sulfur Creek and Valley Creek. Forecasts were also provided for a stock of hatchery-reared PIT-tagged summer-run sockeye salmon from Redfish Lake and for the runs-at-large of Snake River wild yearling chinook salmon, and steelhead trout. The 1999 RealTime project began making forecasts for a new stock of PIT-tagged wild fall subyearling chinook salmon, as a substitute for forecasts of the wild run-at-large, discontinued June 6. Forecasts for the run-at-large were discontinued when a large release of unmarked hatchery fish into the Snake River made identification of wild fish impossible.

The 1999 Program RealTime performance was comparable to its performance in previous years with respect to the run-at-large of yearling chinook salmon (whole season MAD=3.7%), and the run of hatchery-reared Redfish Lake sockeye salmon (whole seasone MAD=6.7%). Season-wide performance of program RealTime predictions for wild Snake River yearling chinook salmon ESUs improved in 1999, with mean MADs from the first half of the outmigrations down from 15.1% in 1998 to 4.5% in 1999. RealTime performance was somewhat worse for the run-at-large of steelhead trout in 1999, compared to 1998, particularly during the last half of the outmigration when the MAD increased from 2.7% in 1998 to 6.1% in 1999. A pattern of over-predictions was observed in half of the yearling chinook salmon ESUs and the steelhead run-at-large during the month of May. Lower-than-average outflows were observed at Lower Granite dam during the first half of May, the only period of low flows in an year with otherwise higher-than-averageflows. The passage distribution of the stock new to the RealTime forecasting project, the PIT-tagged stock of fall subyearling chinook salmon, was predicted with very good accuracy (whole season MAD=4.7%), particularly during the last half of the outmigration (MAD=3.6%).

The RealTime project reverted to a pre-1998 method of adjusting PIT-tagged smolt counts at Lower Granite Dam because of its superior performance during the last half of the outmigration.

Executive Summary

1999 Objectives

1. Refine application of program RealTime to improve precision and accuracy of in-season predictions of the run-timing of the spring/summer-outmigration of wild Snake River yearling chinook salmon, the summer-outmigration of wild Snake River subyearling chinook salmon, the summer-outmigration of hatchery sockeye salmon from Redfish Lake, and the spring/summer-outmigration of wild Snake River steelhead trout at Lower Granite Dam.
2. Predict and report in real-time the “percent run-to-date” and “date to specified percentiles” of the outmigrations at Lower Granite Dam, based on the Fish Passage Center’s (FPC) passage indices and PIT-tag detections from specific release sites.
3. Post on-line Internet-based predictions on outmigration status and trends to improve in-season population monitoring information available for use by the Technical Management Team and the fisheries community to assist river management.

Accomplishments

The RealTime 1999 project tracked and forecasted a total of 16 wild PIT-tagged Snake River spring/summer yearling chinook salmon ESUs. Of these, 11 met RealTime’s historical data requirements. These eleven include Bear Valley Creek, Big Creek, Catherine Creek, Elk Creek, Imnaha River, Lake Creek, Lostine River, Marsh Creek, Minam River, South Fork Salmon River, and Secesh River. As in previous years, ESUs which did not meet data requirements (Cape Horn Creek, Herd Creek, Loon Creek, Sulfur Creek, and Valley Creek) were included in the RealTime project for the dual purpose of providing maximum run-timing information on ESU stocks and continuing to test whether release sites with less data nevertheless provide good predictions. Passage indices provided by the Fish Passage Center at Lower Granite Dam were utilized by the RealTime project to forecast the wild yearling chinook salmon and steelhead runs-at-large, but were unavailable in 1999 for the subyearling chinook salmon run-at-large. The release of nearly 700,000 unmarked hatchery subyearling chinook salmon smolts into the Snake River made differentiation between wild and hatchery stocks by the FPC at Lower Granite dam impossible. To continue to provide information about this run to the fisheries community, a subpopulation of PIT-tagged wild fall subyearling chinook salmon was included in the RealTime forecasting project.

This stock tracks the run-at-large well during the early and middle portions of the outmigration. The objective of providing run-timing forecasts for hatchery-reared sockeye salmon from Redfish Lake based on PIT-tagged smolts was also accomplished in 1999. On-line run-timing predictions were provided via the Internet at *http://www.cbr.washington.edu/crisprt* to the fisheries community throughout each smolt outmigration.

A reversion to a previous (pre-1998) formulation for upwardly adjusting raw counts of PIT-tagged smolts at Lower Granite Dam was used for the 1999 forecasting project. This refinement was made to provide better run-timing forecasts during the last half of the season's outmigrations.

Findings

Season-wide performance of program RealTime predictions for wild Snake River yearling chinook salmon ESUs improved in 1999, and first-half predictions were greatly improved over 1998. (The mean absolute deviance[1] (MAD) of the daily predicted outmigration-percentage from the actual outmigration-percentage is used as measure of accuracy in this and all previous RealTime reports). The mean MAD for the first half of these spring/summer chinook salmon 1999 outmigrations was 4.5% compared to 15.1% in 1998. RealTime performance was somewhat worse for the run-at-large of steelhead trout in 1999, compared to 1998, particularly during the last half of the outmigration when the MAD increased from 2.7% in 1998 to 6.1% in 1999. The 1999 Program RealTime performance was comparable to its performance in previous years with respect to the run-at-large of yearling chinook salmon (whole season MAD=3.7%), and the run of hatchery-reared Redfish Lake sockeye salmon (whole seasone MAD=6.7%). A pattern of over-predictions was observed in half of the yearling chinook salmon ESUs and the steelhead run-at-large during the month of May. Lower-than-average outflows were observed at Lower Granite dam during the first half of May. With the exception of this low-flow period in early May, 1999 was considered a high-flow year starting with higher-than-average flows in late April. The passage distribution of a new RealTime stock, the PIT-tagged stock of fall subyearling chinook salmon was predicted with very good accuracy (whole season MAD=4.7%), particularly during the last half of the outmigration (MAD=3.6%).

1.Mean absolute deviance is the average absolute difference between the predicted proportion and the observed proportion of the outmigration distribution, calculated over the days in the outmigration.

Management Implications

The ability to accurately predict the outmigration status of composite or individual salmon and steelhead stocks at different locations in the Federal Columbia River Power System (FCRPS) can provide valuable information to assist water managers. Since the 1994 outmigration, program RealTime has been applied to provide in-season predictions of smolt outmigration timing for individual and aggregates of listed threatened and endangered Snake River salmon stocks. These predictions have been made available to the fisheries community to assist in-season river management.

Recommendations

In order to maintain the high standards of performance observed in the 1999 RealTime forecasting project, it is recomended that we implement an automated calibration procedure for optimizing the model-switching dynamics of the RealTime algorithm. Such an optimization routine will likely improve predictions for individual ESUs as well as increase the likelihood of high performance for new stocks that need to be added to the project on short notice, such as the 1999 PIT-tagged subpopulation of fall subyearling chinook salmon.

We also recommend continuing to monitor and evaluate ongoing research into passage efficiencies at Lower Granite Dam and the effects of river variables on these passage fractions, in order to produce adjusted counts of raw smolts that most accurately reflect the true numbers of smolts passing Lower Granite dam in their seaward migrations.

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Acknowledgments

We wish to express thanks to the many fisheries agencies, Tribes and other institutions that have expended considerable resources in the generation, assembly, analysis and sharing of Columbia River biological, hydrologic, operational and other related information. Deserving particular thanks are the staff of the agencies and Tribes responsible for conducting the annual Columbia River Smolt Monitoring Program, the Fish Passage Center and the Pacific States Marine Fisheries Commission PIT-Tag Information System (PTAGIS) primary database centers for providing timely in-season access to fish passage and PIT-tag information and the University of Washington second-tier database DART (Data Access in Real Time) information system which receives, processes and provides access to biological, hydrologic and operational information via the Internet. For this year's RealTime forecasting operation, we extend special appreciation to William Connor of the Fish and Wildlife Service for providing the project with PIT-tag data on a subpopulation of the wild Snake River fall subyearling chinook salmon run-at-large, after FPC passage indices became unavailable on June 6, 1999.

Special appreciation is extended to Judy Cress, Susannah Iltis, and Peter Westhagen of the School of Fisheries at the University of Washington for providing critical data management and computer programming support.

Funding support for this work came from the Pacific Northwest region's electrical ratepayers through the Columbia River Fish and Wildlife Program administered by the Bonneville Power Administration, project number 91-051-00.

1.0 Introduction

Regulating the timing and volume of water released from storage reservoirs (often referred to as flow augmentation) has become a central mitigation strategy for improving downstream migration conditions for juvenile salmonids in the Columbia River Basin. Snake River water managers in particular have used flow augmentation to improve the outmigration survival of stocks listed as threatened or endangered under the Endangered Species Act (ESA). Timing the release of water so that the listed stocks are in place to encounter these augmented flows requires knowledge of the status and trend of the stocks' outmigration timing.

In 1993, work was begun under this project to develop real-time predictions of smolt outmigration dynamics for ESA-listed stocks and other runs-at-large for the Snake and Columbia Rivers. The fruit of this labor was the Program RealTime, a statistical software program which predicts run-timing of individual stocks of salmonids (Skalski et al. 1994). It uses historical data to predict the percentile of the outmigration that will reach an index site, in real-time; and it forecasts the elapsed time until some future percentile is observed at that site. The first in-season predictions were of wild spring/summer chinook salmon smolts from the Snake River drainage above Lower Granite Dam in their 1994 outmigrations. These fish originate in streams listed by the National Marine Fisheries Service (NMFS) as evolutionary significant units (ESUs). As parr, a portion of these fish are annually implanted with PIT- (Passive Integrated Transponder, Prentice et al., 1990a, b, c) tags, and released back into their natal streams where they over-winter until their outmigration as yearlings in the spring and summer (Achord et al. 1994, 1995, 1996, 1997, 1998). During outmigration, PIT-tag detectors at Lower Granite Dam read the tag codes so individual stocks can be monitored.

University of Washington fisheries scientists subsequently incorporated Program RealTime predictions into their CRiSP model to move the forecasted runs of these stocks down the Snake and Columbia Rivers to Bonneville Dam (Hayes et al. 1996, Beer et al. 1999, *http://www.cqs.washington.edu/crisprt*).

Since 1994, the RealTime forecasting project has expanded its scope to track and forecast other NMFS-listed populations of Snake River salmonids. In addition to the wild yearling spring/

summer chinook salmon ESUs, program RealTime currently tracks and forecasts the run-timing to Lower Granite Dam of runs-at-large of wild Snake River yearling chinook salmon and steelhead, a PIT-tagged subpopulation of the run-at-large of wild fall subyearling chinook salmon, and a population of hatchery-reared PIT-tagged, summer-run sockeye salmon from Redfish Lake (Townsend et al. 1995, 1996, 1997, 1998, Burgess et al. 1999).

This report presents a post-season analysis of Program RealTime performance for 1999. Here we compare RealTime predictions with observed distributions of fish counts at Lower Granite dam. During the outmigration season, predictions are interactively accessible daily, via the World Wide Web at address *http://www.cqs.washington.edu/crisprt.* The website's end-of-season graphical and tabular displays of Program RealTime results, by stock, are included in Appendices A and B of this report. Appendix A contains the daily record of RealTime predictions compared with the season-end observed distributions for all runs tracked by Program RealTime in 1999, and Appendix B contains historical run-timing information for each stock.

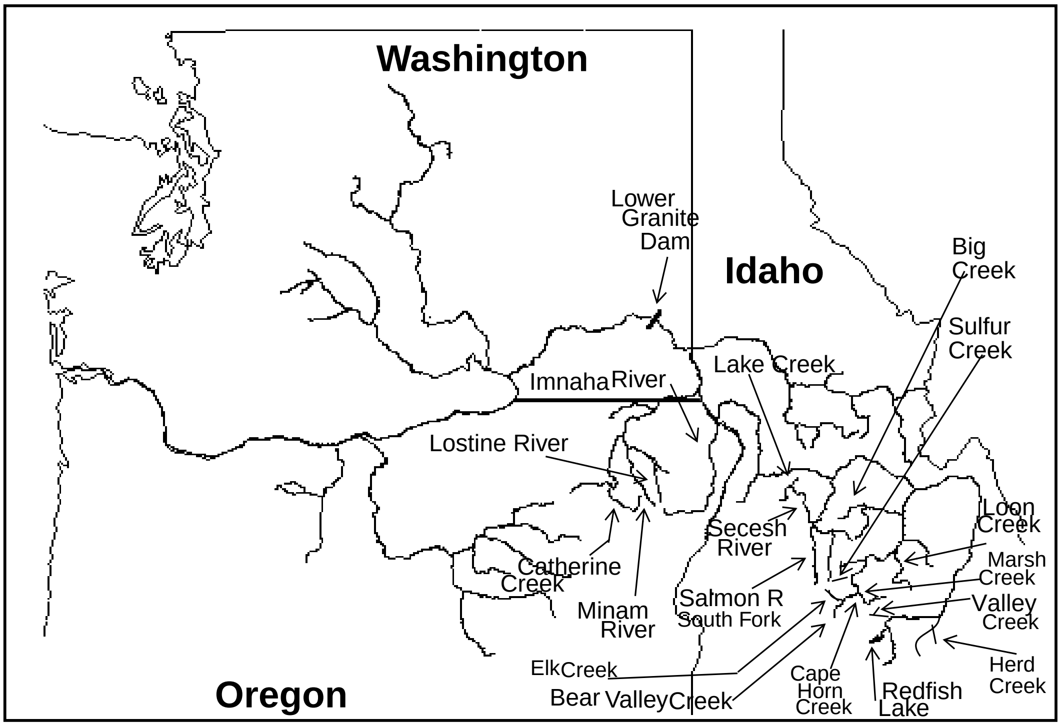
2.0 Methods

2.1 Description of Data

2.1.1 PIT-tag Data

PIT-tag data were made available by the Pacific States Marine Fisheries Commision's PIT Tag Information System (PITAGIS) project. In 1999 we tracked and prepared forecasts of outmigration timing to Lower Granite Dam for PIT-tagged wild yearling spring/summer chinook salmon, wild Snake River fall subyearling chinook salmon, and hatchery-reared, summer-run sockeye salmon from Redfish Lake. The wild yearling chinook salmon originated from sixteen streams or rivers above Lower Granite dam, where they were captured, PIT-tagged, and released as parr between May 31 and November 1, 1998. The wild subyearling chinook salmon were PIT-tagged and released near the confluence of the Salmon and Snake Rivers, into the Snake River above Lower Granite dam during April through July of 1999. Figure 1 shows locations of the release sites and Table 1 displays the U.S. Geological Survey hydrounits for each site.

Figure 1: Map showing PIT-tag/release sites used in forecasting outmigration timing by Program RealTime in 1999, for spring/summer yearling chinook and Redfish Lake sockeye salmon ESUs.



Spring/summer Yearling Chinook Salmon PIT-tag Data

Originally, tag/release sites were chosen on the basis of their consistent recovery numbers (PIT-detections at LGR)[1], and by virtue of having at least three years of historical data, each with at least 30 PIT-tag detections. Over the years, stocks with less historical information were also forecasted in order to determine whether a lower standard would still provide good predictions. In addition we studied “composite runs”, which are the combined data sets from several streams treated as a single stock. The composite runs are “good performers” (produce good predictions) because they smooth and dampen the randomness of individual stocks. They can

1.Detections of PIT-tagged smolts at Lower Granite Dam can be seen as recaptures or recoveries in a mark-release experiment, so the terms “recapture”, “recovery”, and “detection” will be used interchangeably throughout this report.

Table 1: The GIS hydrounits of PIT-tag/release sites for yearling chinook and sockeye salmon included in the 1999 Program RealTime forecasting project. PIT-tagged parr were released at these sites in 1998, and tracked and forecasted to Lower Granite Dam during spring and summer of 1999.

Stream Name (Release Site)	GIS Hydrounits[a]
Bear Valley Creek	17060205
Big Creek	17060206
Cape Horn Creek	17060205
Catherine Creek	17060104
Elk Creek	17060205
Herd Creek	17060201
Imnaha River	17060102
Lake Creek	17060208
Loon Creek	17060205
Lostine River	17060105
Marsh Creek	17060205
Minam River	17060106
Redfish Lake	17060201
Salmon River, South Fork	17060208
Secesh River	17060208
Sulfur Creek	17060205
Valley Creek	17060201

a.Geographical Information System (GIS) designations established by the U.S. Geological Survey.

be useful for providing general run-timing information for groupings of release sites. In 1999 there were three composites. The CRiSP/RealTime composite sites had to meet the extreme data requirements of the CRiSP model. These sites included Catherine Creek, and Imnaha, Minam and South Fork Salmon Rivers. The RealTime Select composite consisted of sites that met the less stringent historical data requirements described above for program RealTime. In addition to the CRiSP/RealTime stocks, these included Bear Valley Creek, Big Creek, Elk Creek, Lake Creek, Lostine River, Marsh Creek, and Secesh River. The third composite was the RealTime All-Stocks composite which included all sites (Figure 1, Table 1).

In order to ensure representative sampling of the wild yearling spring/summer stocks, it was established in 1998 that only Lower Granite PIT-detections of fish tagged and released by experienced taggers Paul Sankovitch and Steve Achord would be used by RealTime. Parr whose tags are implanted by inexperienced taggers or for other experimental reasons could bias the samples. Also, to maintain consistency between pre- and post-1993 PIT-tagging practices, (after 1993, tagging continued into late fall and winter, Ashe et al. 1995, Blenden et al. 1996, Keefe et al. 1995, 1996) we use only detections of fish tagged from May 31 through November 1 of the previous year, since fish marked during different seasons have shown differences in migrational timing to Lower Granite Dam (Keefe et al. 1995, 1996).

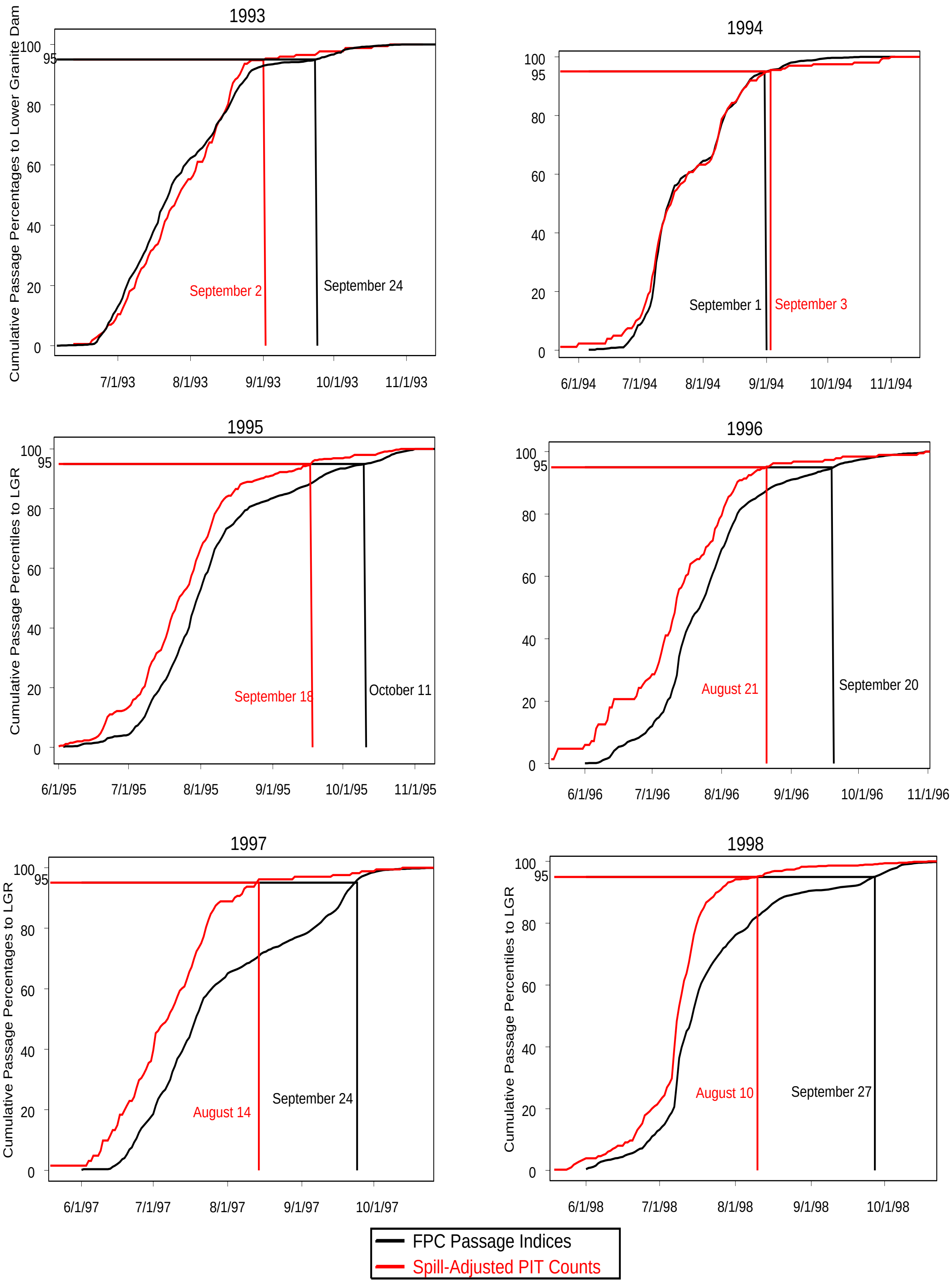
Redfish Lake Sockeye Salmon PIT-tag Data

RealTime forecaster observations of Redfish Lake sockeye PIT-tagged smolts at Lower Granite dam were restricted to fish tagged and released between July 31 and December 31 of the previous year, to ensure consistency of recoveries.

Snake River Fall Subyearling Chinook Salmon PIT-tag Data

In 1999 a PIT-tagged subpopulation of the run-at-large of wild fall subyearling chinook salmon was included in the RealTime forecasting project. It was intended to serve as a kind of surrogate for the wild run-at-large which the RealTime project had tracked for 2 years using FPC passages indices. Passage indices for this run became unavailable after June 6, 1999 (see Section 2.5). Figure 2 shows annual comparisons of the passage distributions of the run-at-large with the PIT-tagged population for 1993-1998. During those years fall subyearling chinook salmon were sampled, PIT-tagged and released back into the Snake River between river kilometers 224 and 268 by William Connor of the USFWS at Dworshak Fisheries Complex as part of his doctoral research. Connor sampled, tagged and released smolts at regular intervals, from April into July or until water temperatures approached 20^{o}C or until catches neared zero. These smolts were tracked at Lower Granite dam from approximately June 1 through October of the same year. The subpopulation mimics the run-at-large passage percentiles well during the first and middle portions of the run.

Figure 2. Passage percentiles of the run-at-large (in FPC passage indices) of fall subyearling chinook salmon compared with spill-adjusted counts from a PIT-tagged subpopulation (see text, this section), 1993-1998.



2.1.2 Passage Index Data

Passage index data were made available by the Northwest Power Planning Council’s (NWPPC) Fish Passage Center (FPC). Passage indices are sample counts in the bypass system at Lower Granite dam divided by the proportion of water passing through the sampling system. They are collected according to FPC sampling plans (Fish Passage Center, 1999), and reflect the size of the run.

Runs-at-large of wild Snake River Yearling Chinook Salmon and Steelhead Trout

Passage indices of run of the river spring/summer yearling chinook salmon and steelhead trout have been tracked and forecasted by program RealTime since 1997. Historical data from 1993 are used to forecast the chinook salmon outmigration and historical data dating from 1991 are used to forecast the steelhead trout run.

2.2 Preprocessing

Raw PIT-tag count data are adjusted for spill fraction (Section 2.3) and smoothed using three 5-day smoothing passes to filter out statistical randomness, before input to the RealTime forecaster algorithm. Raw passage index data are smoothed the same as PIT-data. Passage indices are flow-adjusted by the FPC (Section 2.1.2).

2.3 Adjustment of Raw PIT-tagged Smolt Counts.

Because some PIT-tagged smolts pass Lower Granite Dam undetected by the dam’s PIT-tag detection system, for example through the spillway, the daily number of fish observed, “raw smolt counts” are multiplied by an expansion factor, resulting in “adjusted counts” according to the formula

raw counts x expansion factor = adjusted counts.

It is the adjusted counts which program RealTime uses in forecasting run-timing. In 1999 the expansion factor was

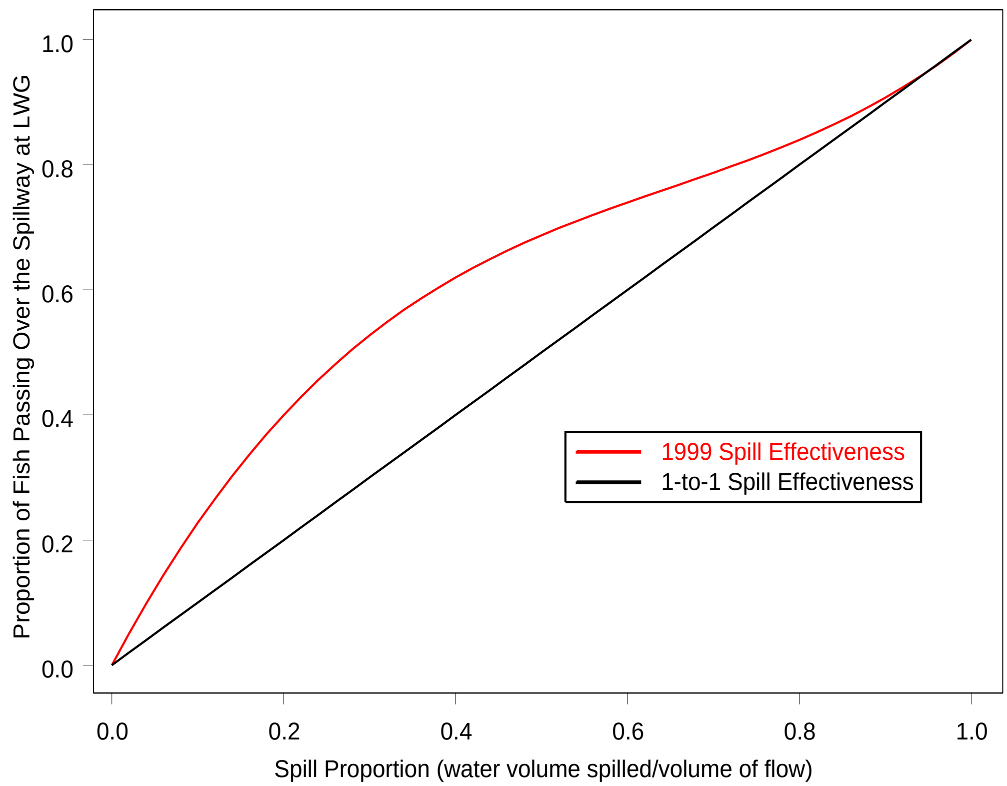
$$\frac{1}{1 - SE},$$

where *SE* is *spill effectiveness*, the fraction of smolts passing through the spillway (NMFS, 2000). Spill effectiveness is given by Smith et al. (1993) as

$$SE = 1.667\left(\frac{S}{F}\right)^3 - 3.25\left(\frac{S}{F}\right)^2 + 2.583\left(\frac{S}{F}\right). \tag{1}$$

where S is the daily volume of water spilled and F is daily outflow volume (Figure 3).

Figure 3. Spill effectiveness (SE) function (equation 1) used by Program RealTime to upwardly adjust raw PIT-tag detections. Shown is the 1999 RealTime spill effectiveness curve as a function of spill proportion (S/F) compared with a 1-to-1 function.

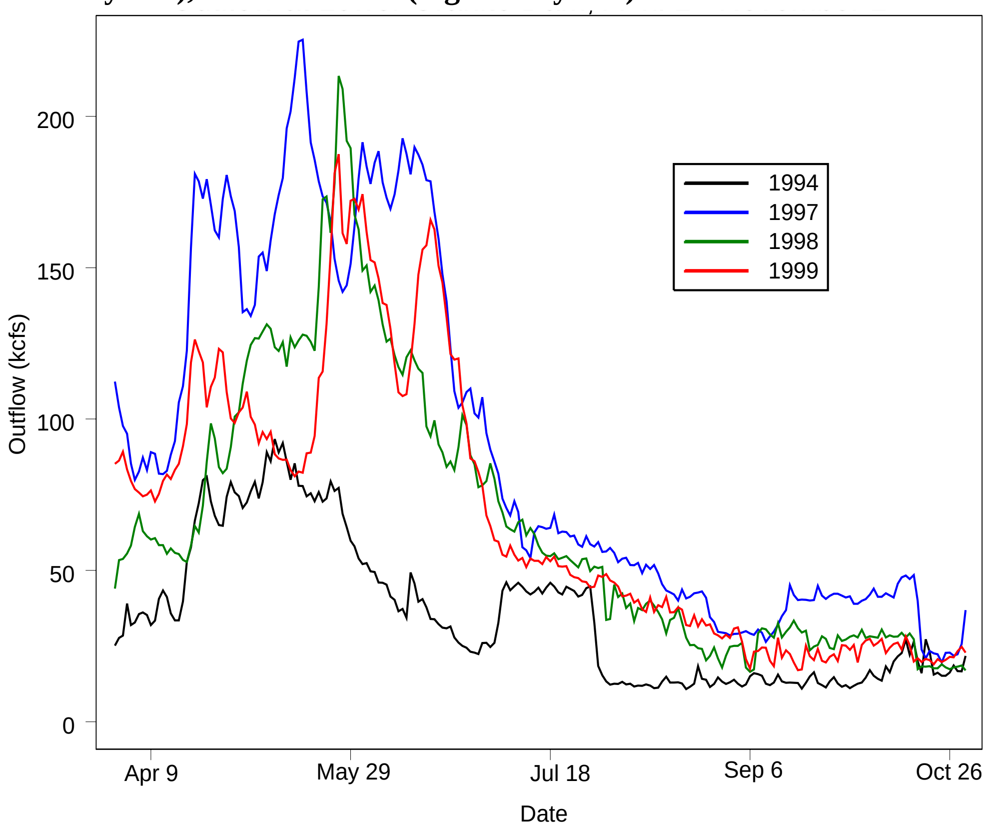


The adjustment process used in 1999 was a return to pre-1998 methods. In 1998, a formulation taking fish guidance efficiency (FGE) into account was used (Burgess et al., 1999). This method was abandoned when post-season analysis showed greater accuracy from pre-1998 methods for the last half of the runs.

2.4 Outflow at Lower Granite Dam

Although it has not been conclusively demonstrated, flow (which is highly correlated with a number of other river variables, such as turbidity and temperature) is thought to substantially affect wild fall subyearling chinook salmon outmigration timing to Lower Granite Dam (Connor, et al. 1994b and 1996; Giorgi and Schlechte 1997; Smith et al.1997). Flow surges may influence the numbers of fry that migrate from upriver spawning grounds (Healey, 1991). The 1999 flow year was considered a high flow year like 1997 (Figure 4), relative to standard flow years such as 1998 and 1994.

Figure 4. Outflow volumes at Lower Granite Dam, April 1-November1, for 1994, 1998 (standard flow years), 1997 and 1999 (high-flow years).



2.5 Migration Year 1999.

The most notable event of migration year 1999 was the release, by Big Canyon and Captain John Landing hatcheries, of 670,000 unmarked hatchery subyearling chinook salmon into the Snake River, an occurrence which spelled the demise of the tracking of the wild Snake River subyearling chinook salmon run-at-large by the Fish Passage Center. It is fundamental to the RealTime forecasting process to distinguish the wild stock from hatchery stocks, so this event forced the discontinuance of the RealTime forecasting of this outmigration. Program RealTime cannot forecast for the run-at-large when it includes hatchery stocks because hatchery release practices are highly variable. Their large releases vary in both timing and stock composition and effectively obliterate the signature pattern of wild fish passage. The fall subyearling chinook salmon releases took place on June 3 and 5 of the 1999 migration year. It is thought the release of unmarked fish from hatcheries will become routine practice in the future (Larry Basham, FPC, pers. comm., June, 1999).

In order to continue providing information to the fisheries community about this run, we began to track and produce run-timing forecasts and passage percentile predictions for a PIT-tagged subpopulation of wild fall subyearlings (Section 2.1.1). The subpopulation is thought to accurately represent passage events for the run-at-large during the early and middle portions. Tagger Connor's experience with sampling wild fall subyearling chinook salmon allowed him to accurately differentiate between wild and hatchery fish (personal communication, June 1999) easily during the first part of the run in 1999, although he expected that differentiation would prove more difficult later on.

2.6 Models

2.6.1 The RealTime Forecasting Algorithm

The RealTime forecaster is essentially a pattern-matching algorithm. However, at the beginning of the outmigration there is very little in the way of a pattern to match. To optimize predictions for all phases of the outmigration, the forecaster utilizes three models: a start-up model for initial predictions, the pattern-matching model, and a switching model to govern the timing of the switch between the start-up and pattern-matching models.

The pattern-matching portion is accomplished by a least-squares (LS) model, where the patterns are cumulative percentage curves of outmigrating smolts. Current-year data are compared with historical cumulative percentage curves by comparing their slopes at each percentile, $j = 1, \ldots, 100$, using the measure

$$\sum_j (s_j - s_{ijp})^2 \ , \tag{2}$$

where s_j is the slope at the j^{th} percentile of current-year data to-date and s_{ijp} is slope at the j^{th} percentile of p percent of historical year i 's outmigration curve. The value of p that minimizes (2), i.e.,

$$\min_p \left[\sum_{j=1} (s_j - s_{ijp})^2\right], \qquad p = 0, \ldots, 100 \tag{3}$$

is the best predictor from the point of view of pattern-matching to historical year i.

The start-up model produces run-percentage (RP) estimates

$$\frac{x_d}{E(\hat{S})}, \tag{4}$$

where x_d is the total number of fish observed by day d of the outmigration, and $E(\hat{S})$ estimates the total expected outmigration to Lower Granite dam. The expectation is estimated differently, depending on the type of data. For PIT-tagged stocks, $E(\hat{S})$ is equal to $\bar{r}\ x\ N$, where $\bar{r}$ is the average historical recapture percentage (detections divided by “releases”, the number of PIT-tagged fish released at a particular site per year) at Lower Granite dam, and N is total releases the previous year for PIT-tagged stocks. Tables 2 and 3 display the information used by program Realtime to compute these estimates. For passage index data, $E(\hat{S})$ is simply the average historical run size. Table 4 displays these estimates for yearling chinook salmon and steelhead trout runs-at-large.

Table 2: Data used by program RealTime in 1999 to compute initial predictions (formula 4), for wild Snake River spring/summer yearling chinook salmon ESUs, and hatchery-reared Redfish Lake summer sockeye salmon. Column (1) is the number, N, of PIT-tagged parr released in 1998, by site. Columns (2) and (3) are the raw and adjusted numbers, respectively, of PIT-tagged smolts detected at Lower Granite Dam in migration year 1999. Columns (4) and (5) show historical recapture percentages and number of years of historical data, respectively, for each site. Column (6) shows the 1999 recapture percentages (col.3/col.1).

Tagging Location	(1) 1998 Parr Pit-tagged	(2) 1999 Raw PIT Detections	(3) 1999 Adjusted PIT Detections	(4) Number Years of Historical Data	(5) Average Historical Recapture Percentages, $\bar{r}$	(6) 1999 Recapture Percentages[a] (col.3/col.1)
Bear Valley Creek	820	39	92.2	7	11.8	11.2
Big Creek	1427	96	232	6	9.7	16.3
Cape Horn Creek	270	15	35.8	4	12.4	13.3
Catherine Creek	504	20	49.6	8	13.4	9.8
Elk Creek	700	44	99.1	6	15.0	14.2
Herd Creek	959	56	131.6	3	7.6	13.7
Imnaha River	1009	40	95.3	10	12.5	9.4
Lake Creek	545	20	47.1	6	10.9	8.7
Loon Creek	1029	71	173.5	3	12.9	16.9
Lostine River	506	19	45	7	13.6	8.9
Marsh Creek	769	53	126.6	6	9.8	16.5
Minam River	1006	47	110.3	6	14.8	11.0
Redfish Lake	4179	58	143.9	4	5.0	3.4
Salmon River, SF	998	38	87.6	9	9.6	8.8
Secesh River	938	35	78.3	10	11.2	8.3
Sulfur Creek	443	17	42.1	4	8.7	9.5
Valley Creek	1001	50	118.0	7	4.3	11.8

a.Data Sources: PTAGIS Database and RealTime program output as of 22 September 1999.

Table 3: Data used by program RealTime in 1999 to compute initial predictions, (formula 4 in text), for wild Snake River fall subyearling chinook salmon. Column (1) is the number, N, of PIT-tagged smolts released in April through July of 1999 near the confluence of the Snake and Salmon Rivers. Columns (2) and (3) show the raw and adjusted numbers, respectively, of PIT-detections at Lower Granite Dam for 1999. Columns (4) and (5) show the historical recapture percentages and the number of years of historical data, respectively, and column (6) shows the 1999 recapture percentage (col.3/col.1).

Tagging Location	(1) Apr-Jul Smolts Pit-tagged, N	(2) Jun-Nov, Raw PIT Detections	(3) Jun-Nov Adjusted PIT Detections	(4) Years of Historical Data	(5) Average Historical Recapture Percentage, $\bar{r}$	(6) 1999 Recapture Percentage[a]
Snake River, river km 224-268	1760	592	835.5	6	26.1	47.5

a.Data Sources: PTAGIS Database and RealTime program output as of 22 September 1999.

Table 4: Data used by program RealTime to compute initial predictions (formula 4 in text), for FPC passage indices of the runs-at-large of wild steelhead trout and yearling chinook salmon at Lower Granite Dam. The passage indices reflect total run size.

Year	Steelhead Trout	Yearling Chinook Salmon
1990	628771	---
1991	583740	---
1992	576536	---
1993	517244	374138
1994	485203	334022
1995	525732	865290
1996	435069	214106
1997	754499	80861
1998	502128	373736
1999	628771	636314

The RP estimates, (4), are more accurate than LS (pattern-matching) estimates (3) initially, but are quickly outperformed by LS estimates as the season progresses (Townsend et al., 1995, 1996, 1997).

The switching model is an age-of-run (AR) model based on mean fish run age (MFRA). Thus each model produces its own estimate of the true passage percentile.

The algorithm selects the best $p = 0, \ldots, 100$ by combining the three (LS, RP, and AR) model estimates and their estimated errors into a nonlinear combination. The estimated error for the LS model was given in (2) above, and the estimated errors for the RP and AR models are, respectively,

$$\left| \log p - \log \hat{RP} \right|, \quad p = 0, \ldots, 100 \tag{5}$$

and

$$\left| \log p - \log \hat{AR} \right|, \quad p = 0, \ldots, 100, \tag{6}$$

where $\hat{RP}$ in (5) is the RP model estimator (4) and $\hat{AR}$ in (6) is the AR model estimate, based on MFRA. For a complete description of the algorithm's mathematical details, see Burgess, et al., 1999. By including age-of-run (AR) and run percentage (RP) information, the forecaster effectively combines these indicators together with the least-squares (LS) pattern-matching model into a single, more accurate and robust predictor.

2.6.2 Precision of Estimator: Confidence Intervals for $\hat{P}$

Each day of the run, a jackknife confidence interval is constructed for the daily prediction estimate, $\hat{P}$, the best choice of the p's, $p = 0, \ldots, 100$, in section 2.6.1. Jackknifing is a computer-intensive method of extracting sampling distribution information about an estimator by recomputing the estimator from different subsets of the historical data. A jackknife subset consists of the complete set of historical years minus one year. If a release site has, say, 6 years of historical data, there will be 6 subsets of 5 years each. A prediction is estimated from each subset, and these jackknife predictions provide a measure of dispersion on which the daily confidence interval is based.

2.6.3 Evaluating RealTime Performance

The true outmigration percentile on day d (i.e., P_d) can only be observed after the run is finished (i.e. $P_{last} = 100\%$). When the run is over, we evaluate RealTime's performance using the mean of the absolute differences (MAD) between observed outmigration percentiles, P_d, and their estimates, $\hat{P}_d$, for all days, d:

$$MAD = \frac{\sum_{d=1}^{n} \left|\hat{P}_d - P_d\right|}{n} \qquad (7)$$

where n is the total number of days in the outmigration run for the season.

3.0 Results

3.1 Wild PIT-tagged Spring/Summer Yearling Chinook Salmon ESUs

Table 5 shows the mean absolute deviations of RealTime predictions for 1999 compared to 1998 MADS where applicable. The daily absolute differences are averaged over the entire run, and separately over the first and last halves of the season.

In general, the performance of Program RealTime was quite good this year for the spring/summer chinook salmon ESUs, as can be seen from the daily prediction records (Appendix A) and the MADs (Table 5). The RealTime Select composite-run predictions (Figure 5) were, on average, within 2% (MAD=1.92%) of the true passage percentile for the whole-season run, within 1% (MAD=1.00%) over the first half, and within 3% over the last half (MAD=2.34%). The Select composite consists of those sites (in bold) meeting the original RealTime historical data requirements (Section 2.2.1).

Whole-season MADs for 1999 showed improved season-wide performance relative to previous years. Extremes of performance, good and bad, were evenly mixed among the first and second halves of the season, for spring/summer yearling chinook salmon ESUs in 1999. This is in marked contrast to the 1998 migration, which showed record-high first-half MADS, coupled with normal or better-than-average last-half MADs, for almost every site.

Table 5: Mean absolute deviations (MADs, section 2.6.3) for the 1998 and 1999 outmigrations to Lower Granite Dam of 16 wild PIT-tagged Snake River spring/summer yearling chinook salmon ESUs and composite runs (section 2.1.1). Columns show MADs for the entire run, the first 50% of the run, and the last 50% of the run. Sites in bold are RealTime Select Composite release sites (section 2.1.1).

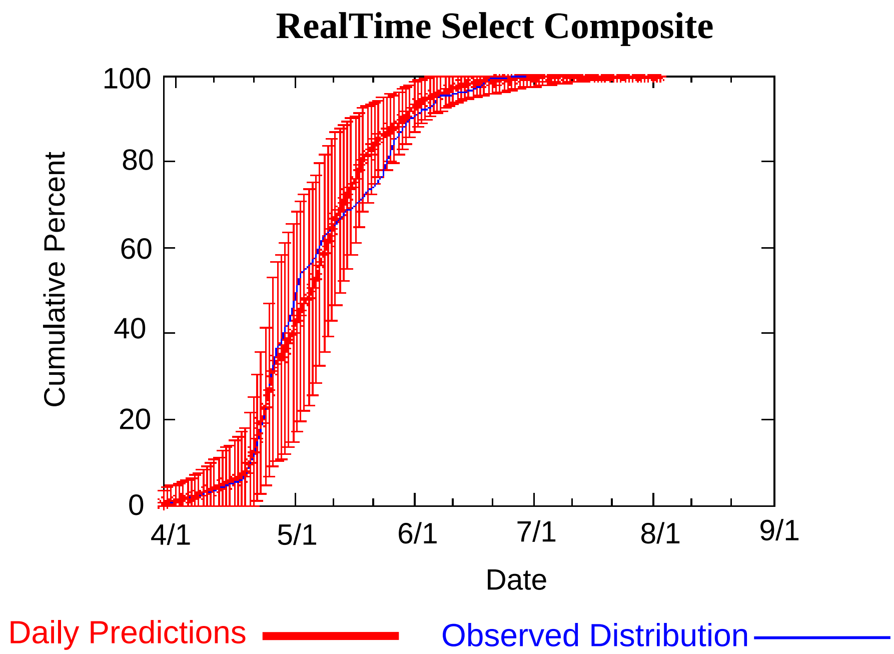
Tagging Site	1998			1999		
	Entire Run, %	First 50%, %	Last 50%, %	Entire Run, %	First 50%, %	Last 50%, %
Bear Valley Creek	8.0	8.6	7.7	8.13	1.42	9.63
Big Creek	---	---	---	2.78	3.70	2.34
Cape Horn Creek	---	---	---	8.33	8.43	8.26
Catherine Creek	8.4	7.6	8.8	6.24	4.04	7.67
Elk Creek	12.5	26.8	6.4	3.59	0.36	4.87
Herd Creek	---	---	---	5.08	5.51	4.69
Imnaha River	10.6	20.6	4.5	3.40	3.88	3.18
Lake Creek	8.7	19.7	6.1	3.20	1.66	3.60
Loon Creek	---	---	---	8.77	12.94	6.60
Lostine River	---	---	---	5.79	4.38	8.08
Marsh Creek	---	---	---	3.97	6.79	3.00
Minam River	7.8	16.3	3.5	5.83	2.79	7.84
Salmon River, South Fork	4.3	6.6	3.4	5.89	0.92	10.15
Secesh River	6.5	14.8	4.5	3.93	1.21	4.85
Sulfur Creek	---	---	---	9.12	6.58	11.88
Valley Creek	---	---	---	7.40	7.47	7.37
mean MAD[a]	8.4	15.1	5.6	5.72	4.51	6.50
median MAD[a]	8.2	15.6	6.3	5.86	4.21	6.98
range[a]	4.3 - 12.5	6.6 - 26.8	3.4 - 8.8	2.78 - 9.12	0.36 - 12.94	2.34 - 11.88
mean MAD of RealTime Select composite sites[b]	---	---	---	4.80	2.82	5.93
Select Composite Run[c]	---	---	---	1.92	1.00	2.34
CRiSP/RealTime Composite Run	2.6	6.7	1.5	2.5	2.7	2.5

a. These statistics are based on all release sites for the given year.

b. These statistics based on RealTime Select Composite sites only: Bear Valley Creek, Big Creek, Catherine Creek, Elk Creek, Imnaha River, Lake Creek, Lostine River, Minam River, and South Fork Salmon River, Secesh River for both years.

c. Combined data from RealTime Select composite sites, forecasted as a single population.

Figure 5: RealTime Select Composite-run: daily predictions with jackknifed confidence intervals (red) compared to the observed run (blue).



The RealTime CRiSP composite run for spring chinook salmon was substantially improved from last year during the first-half of the season, down from a MAD of 6.7% in 1998 to a MAD of 2.7% in 1999. Season-wide performance of this composite improved slightly in 1999, down to a MAD of 2.5% from a MAD of 2.6% in 1998. Sites belonging to the RealTime CRiSP composite, being comparatively data-rich, are generally better performers than other sites. This year three out of the four CRiSP/RealTime sites improved in performance for the season-wide run, relative to 1998. The one that didn't improve, South Fork Salmon River, still performed quite well, with a season-wide MAD of 5.9%, up from 4.3% in 1998. The slight deterioration in performance was due to an increased MAD for the last-half of the season, up from 3.4% in 1998 to 10.2% in 1999. However, in the first-half of the season performance was astonishingly good, down to 0.9% from an already respectable 6.6% in 1998.

Interestingly, the smallest MAD in 1999 was for Elk Creek during the first half of the season (MAD=0.4%). This statistic was 26.8% in 1998, when it ranked the largest of the 1998 MADS. Several other streams showed excellent performance during the first half of the season as well, with predictions falling within 2% of observed percentiles, on average, for Bear Valley Creek, Elk Creek, Lake Creek, South Fork of the Salmon River, and the Secesh River. The largest first-half MAD was for Loon Creek (MAD=12.9%), which is comparatively data-poor.

The largest last-half of the season MADs were for Sulfur Creek and South Fork Salmon River (11.88% and 10.15%, respectively). The figures in Appendix A reveal a pattern of over-prediction during the period May 1 through June 1 (see figures for Bear Valley Creek, Cape Horn Creek, Elk Creek, Loon Creek, Minam River, South Fork Salmon River, Sulfur Creek and Valley Creek). There is a concurrent dip in flow volume during the first half of May relative to the higher-than-average-flow conditions late April. Outflow volume in the first half of May was below average relative to previous years as well (1993-1999).

The season-wide average MAD, over all sites, was a very low 5.7% for 1999, compared to 8.4% for 1998. The average first-half MAD over all sites was 4.5% in 1999 compared to 15.1% in 1998. For the last half of the season, average MADs were 6.5% and 5.6% for 1999 and 1998, respectively.

Figure 6 and Table 6 compare the percentile-passage dates of the individual stocks and the composite runs. Figure 6 shows the distance of the release sites above Lower Granite Dam, in river kilometers. The middle 80% of the RealTime Select and CRiSP/RealTime composite runs (dashed lines) contains the 50th percentile of smolt passage (red dots) for all the release sites. A lagging of migration timing for longer migration distance is somewhat apparent this year. Appendix B contains detailed historical outmigration information for each of the 16 release sites tracked in 1999.

Table 6: End-of-season 1999 passage dates at Lower Granite Dam (for 0%, 10%, 50%, 90% and 100% passage) of 16 PIT-tagged wild Snake River spring/ summer yearling chinook salmon ESUs, and their composite runs (section 2.1.1).

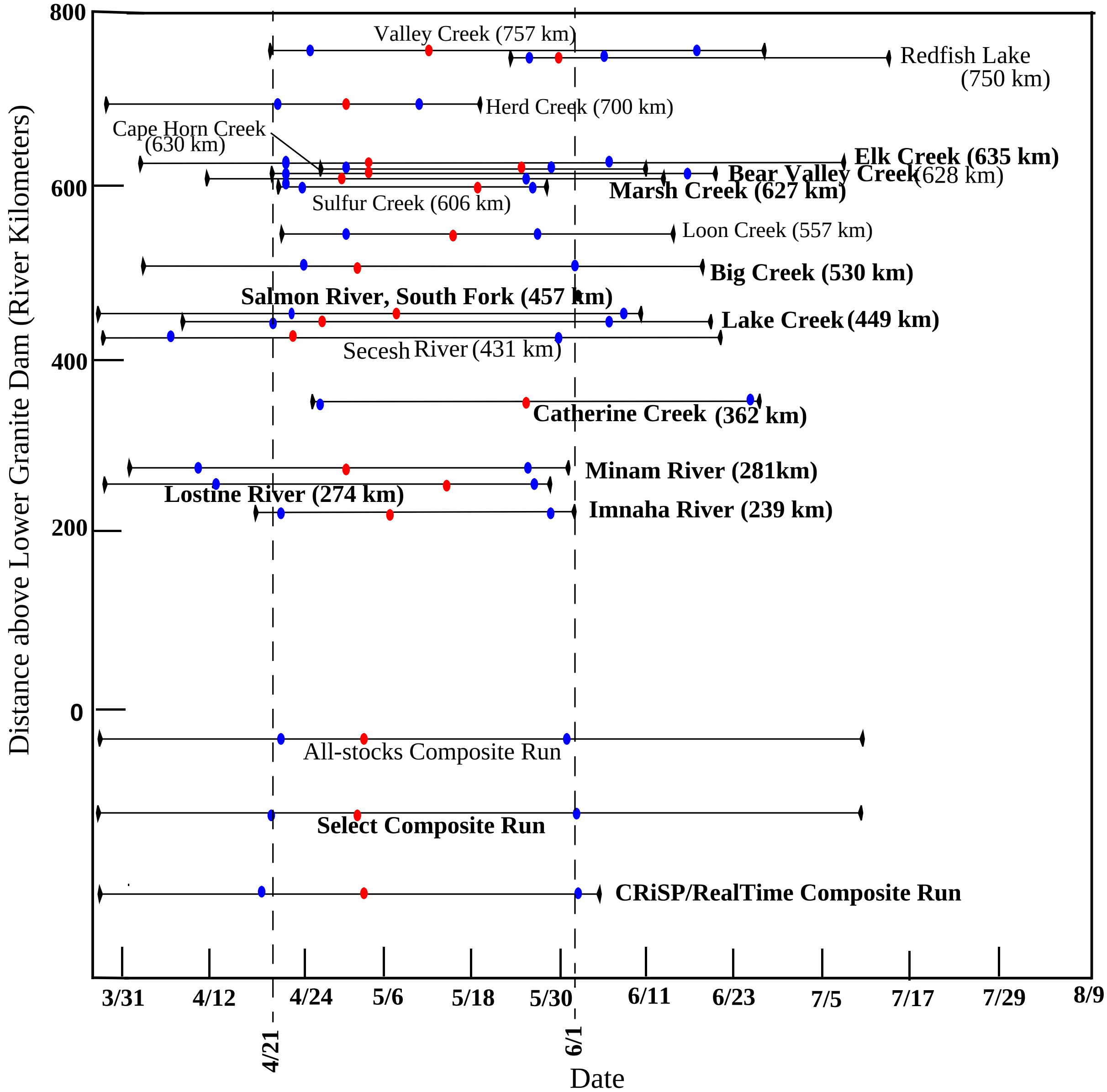
Population or Stock	Passage Dates at Lower Granite Dam 10%	50%	90%	Range (0-100%)
Bear Valley Creek	04/23	05/04	06/16	04/20-06/21
Big Creek	04/24	05/03	06/02	04/04-06/19
Cape Horn Creek	04/29	05/22	05/29	04/25-06/12
Catherine Creek	04/26	05/26	06/17	04/26-06/26
Elk Creek	04/22	05/03	06/06	04/01-07/08
Herd Creek	04/22	04/30	05/09	03/30-05/20
Imnaha River	04/22	05/07	05/29	04/17-06/03
Lake Creek	04/20	04/26	06/05	04/08-06/20
Loon Creek	04/29	05/16	05/27	04/22-06/16
Lostine River	04/13	05/15	05/28	03/29-05/29
Marsh Creek	04/22	05/01	05/25	04/11-06/13
Minam River	04/12	05/01	05/25	03/31-06/02
Redfish Lake	05/26	05/30	06/06	5/25-7/13
Salmon River, South Fork	04/22	05/08	06/08	03/27-06/11
Secesh River	04/06	04/23	05/30	03/29-06/21
Sulfur Creek	04/24	05/19	05/27	04/22-05/29
Valley Creek	04/25	05/13	06/19	04/19-07/01
CRiSP RealTime Composite[a]	04/19	05/04	06/01	03/27-06/26
Select Composite[b]	04/21	05/03	06/01	03/27-07/08
All-stocks composite[c]	04/22	05/04	05/31	03/27-07/08

a. The RealTime Composite includes the release sites Catherine Creek, Imnaha, Minam and South Fork Salmon Rivers, those streams that met CRiSP RealTime historical criteria defined in the text.

b. The Select Composite includes the release sites Bear Valley Creek, Big Creek, Catherine Creek, Elk Creek, Imnaha River, Lake Creek, Lostine River, Marsh Creek, Minam River, South Fork, Salmon River, and Secesh River.

c.The All-stocks Composite combines data from all 16 release sites.

Figure 6. Run-timing plots of 1999 passage dates (10%, 50%, 90% (dots) and range (end-points), data from Table 6) at Lower Granite Dam for wild Snake River spring/summer yearling chinook salmon ESUs and composites (section 2.1.1), and the Redfish Lake sockeye salmon ESU. Vertical axis gives distance in river kilometers of release sites to Lower Granite Dam. Dashed lines show dates of 10% and 90% passage for the RealTime Select composite run. Sites in bold were included in the Select composite.



3.2 Hatchery-reared Redfish Lake Sockeye Salmon ESU

Redfish Lake sockeye are summer-run fish that are hatchery-reared. The 1999 outmigration was similar to that of 1998 with respect to recapture percentages, i.e., number of detections relative to releases (see Table B17, Appendix B). The run was short compared to other years, with the middle 80 percent of the outmigration taking only 11 days. This is the shortest middle 80% passage on record for this stock, which has a historical average of 22 days. The effect of the short run on predictions is apparent in Figure A9 (Appendix A) in which the observed distribution is nearly vertical to 80 percent passage. Over the five years of forecasting by program RealTime, run-timing and recapture percentages have been highly variable. The high variability has been an impediment to forecasting accuracy, compared to that achieved for the spring/summer PIT-tagged yearling chinook salmon ESUs. The MAD for the full-season run in 1999 was comparable to 1998 with predictions for both years falling within 7% of the true percentile (Table 7). There was a considerable improvement from 1998 in the first-half prediction, with MAD down from 12.3% in 1998 to 6.9% in 1999. The last-half MAD for 1999 was slightly higher than 1998.

Table 7: Mean absolute deviations (MADs, section 2.6.3) for the 1998 and 1999 outmigrations to Lower Granite Dam of the PIT-tagged hatchery-reared Redfish Lake sockeye salmon ESU. Columns show MADs for the entire run, the first 50% of the run, and the last 50% of the run.

	1998			1999		
Run	Entire Run	First 50%	Last 50%	Entire Run	First 50%	Last 50%
Redfish Lake Sockeye	6.3	12.3	4.9	6.74	6.91	6.72

3.3 Wild PIT-tagged Fall Subyearling Chinook Salmon ESU

The MAD for the last half of the outmigration of this PIT-tagged subpopulation of the wild fall subyearling Snake River run-at-large was 3.6%, quite a good performance for Program Realtime on a stock (Table 8). First-half performance wasn't quite as good (MAD=9.5%), while the whole-run performance was good (MAD=4.7%).

This fall subyearling chinook salmon stock was included in the RealTime forecasting project as a surrogate for the larger population of Snake River fall subyearling chinook salmon run-at-large that was no longer trackable (see section 2.5).

Table 8: Mean absolute deviations (MADs) for the 1999 outmigration to Lower Granite Dam, of the PIT-tagged subpopulation of the wild Snake River fall subyearling chinook salmon run-at-large. Columns show MADs for the entire run, the first 50% of the run, and the last 50% of the run.

Stock	1999		
	Total Run	First 50%	Last 50%
Wild PIT-tagged Fall Subyearling Chinook Salmon	4.70	9.46	3.62

3.4 Wild Yearling Chinook Salmon and Steelhead Trout Runs-at-Large

The 1999 run of wild yearling chinook salmon was unusually large and the steelhead trout run also was larger than average (Table 4). The MADs for these runs in 1999 were larger than in 1998 (Table 9, Appendix A), and in the case of steelhead, quite large. The large run size for yearling chinook salmon produced an initial over-prediction due to unusually large numbers of smolts seen early in the run). First-half MAD for this run was 10.15% in 1999 compared to 6.4 in 1998. The season-wide MAD was still good at 3.66%, although larger than the 1998 values of 1.8%. First-half MAD for the wild steelhead run increased from 2.7% in 1998 to 6.06% in 1999. Even more dramatic for this run was the increase in last-half MAD from 0.6% in 1998 to 9.19 in 1999. The season-wide MAD increase to 8.54% this year compared to 1.0% in 1998. Low-flow conditions in early May (relative to high-flows in late April) occurred concurrently with a large gap between RealTime predictions and observed percentiles for steelhead trout in 1999 (Figure A10).

Table 9: Mean absolute deviances (MADs, section 2.6.3) for the 1998 and 1999 outmigrations to Lower Granite Dam of FPC passage indices of the wild Snake River steelhead trout and yearling chinook salmon runs-at-large. Columns show MADs for the entire run, the first 50% of the run, and the last 50% of the run.

	1998			1999		
Run-of-Year	Entire Run	First 50%	Last 50%	Entire Run	First 50%	Last 50%
Wild Yearling Chinook Salmon	1.8	6.4	1.0	3.66	10.15	2.28
Wild Steelhead Trout	1.0	2.7	0.6	8.54	6.06	9.19

4.0 Discussion

Due to increased PIT-tagging of wild spring/summer yearling chinook salmon parr in the Snake River drainage system, each year there are more ESUs represented in larger numbers of PIT-detections at Lower Granite dam, and the RealTime forecasting project has accordingly increased the number of wild yearling chinook salmon ESU outmigrations it forecasts. This year the RealTime project included 16 ESUs of spring/summer yearling spring summer chinook salmon, four from the Grande Ronde and twelve from the Salmon River tributaries of the Snake. Eleven of the sites met the RealTime data requirements on number of historical releases and observations (section 2.1.1). The five streams that did not meet the RealTime historical data requirements also performed quite well with an average season-wide MAD of 7.74%, compared to an average MAD of 4.80% for the streams which did meet RealTime’s data requirements.

The year was unremarkable with respect to run-timing and detection rates of PIT-tagged stocks of spring/summer yearling chinook salmon. The runs-at-large of steelhead trout and yearling chinook salmon were larger than average in 1999. The ESU of hatchery-reared sockeye from Redfish Lake had an unusually short run in 1999. RealTime performance for this stock was somewhat improved over previous years, despite the high variability in its four years of historical data.

There was an observed pattern of overprediction during the month of May for eight of 16 spring/summer yearling chinook salmon ESUs, and for the steelhead run-at-large which performed poorly compared to previous years. Year 1999 was considered a high-flow year but there was a dip in flow volume during the month of May.

A new stock of PIT-tagged subyearling fall chinook salmon was included in the RealTime project this year. Program RealTime performed well, predicting passage percentiles to within 4% of the observed distribution, on average, over the outmigration season. How well these data serve to provide information about the 95th percentile of the subyearling fall chinook salmon run-at-large is questionable.

5.0 Recommendations

Additional refinements to the RealTime project of forecasting run-timing and passage distribution of ESA-listed species of salmonids outmigrating to Lower Granite are recommended in order to improve the reliability of inseason predictions made by Program RealTime. These efforts include *a)* implementation of an automated calibration process for Program RealTime, *b)* continued monitoring of research results affecting our count adjustment process. This process, designed to maximize the accuracy of smolt count data, expands raw detections of PIT-tagged smolts at Lower Granite Dam by accounting for the undetected fraction passing through the spillway.

5.1 RealTime Calibration

Research into optimizing the RealTime algorithm's model-switching mechanism (see Models, section 2.6) for individual stocks is likely to yield results that will improve forecasting performance. An automatic calibration procedure which would systematically and exhaustively search for the best weighting mechanisms will not only ensure optimal performance for new stocks added on short notice (e.g., this year's PIT-tagged subpopulation of fall subyearling chinook salmon) but may improve performance of currently-tracked stocks, while potentially adding to our understanding of these stocks' outmigration dynamics.

5.2 Adjustment of Data

Research has shown that different salmonid species have different characteristics of passage through hydroelectric projects, and that these passage parameters vary among hydroelectric projects. In addition passage efficiencies can be affected by river variables such as temperature and flow volume. Continued monitoring and evaluation of research into these important questions affecting passage at Lower Granite dam and fish count adjustments is recommended.

6.0 Conclusions and Summary

The performance of program RealTime in predicting passage percentages and forecasting run-timing characteristics was very good overall in 1999. Performance improved over previous years for the spring/summer yearling chinook salmon ESUs, which included more individual stocks than any previous year, including several streams that did not meet the original historical data criteria for Program RealTime. RealTime forecasting for 1999 showed improved whole-run performance over 1998 and greatly improved first-half predictions. RealTime's forecasting of run-timing for the run of hatchery-reared Redfish Lake Sockeye improved somewhat over previous years. The variability in the historical data for this stock is high compared to wild yearling chinook salmon stocks.

There was a pattern of overprediction in eight of 16 yearling chinook salmon ESUs concurrently with a dip in flow volume at Lower Granite dam in early May. Despite the low outflows in early May, 1999 was considered a high-flow year at Lower Granite dam.

The passage percentiles for the run-at-large of Snake River wild steelhead were over-predicted during the last half of the season, particularly during the month of May, and yearling chinook salmon were over-predicted throughout the season. Prediction performance for the steelhead run was unusually poor this year, particularly for the last half of the outmigration.

A subpopulation of PIT-tagged wild fall subyearling chinook salmon was tracked and forecasted by Program RealTime in 1999 in order to provide information about the run-at-large of wild subyearling chinook salmon. We were unable to track the run-at-large this year because a large influx of unmarked hatchery fish rendered identification of wild fish by the FPC impossible. The passage percentiles for this PIT-tagged population, which has six years of historical data, were predicted with considerable accuracy by Program RealTime during the last half of the season and for the whole run. The high performance reflects high consistency in the historical data, but the relevance of tracking this stock as a surrogate for run-at-large passage is questionable.

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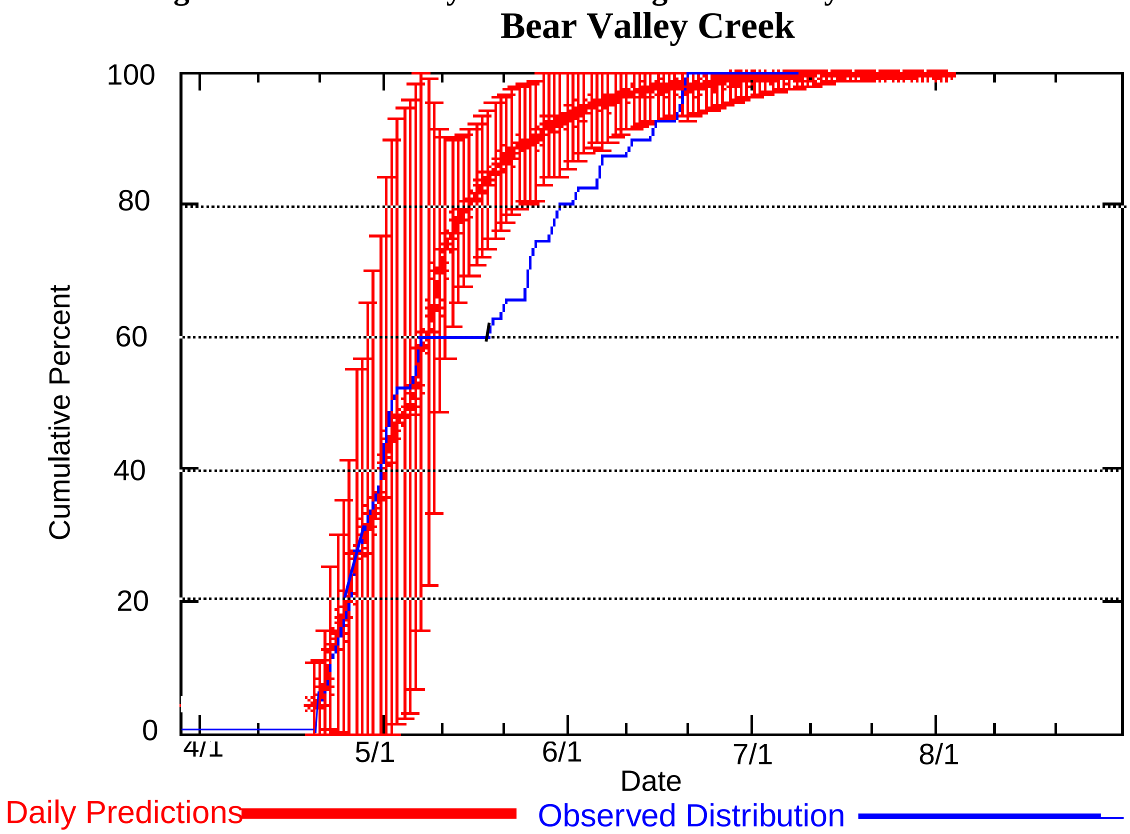
Appendix A

Performance Plots for the 1999 Out-migration Season

Figure A1: Bear Valley Creek and Big Creek Daily Predictions.



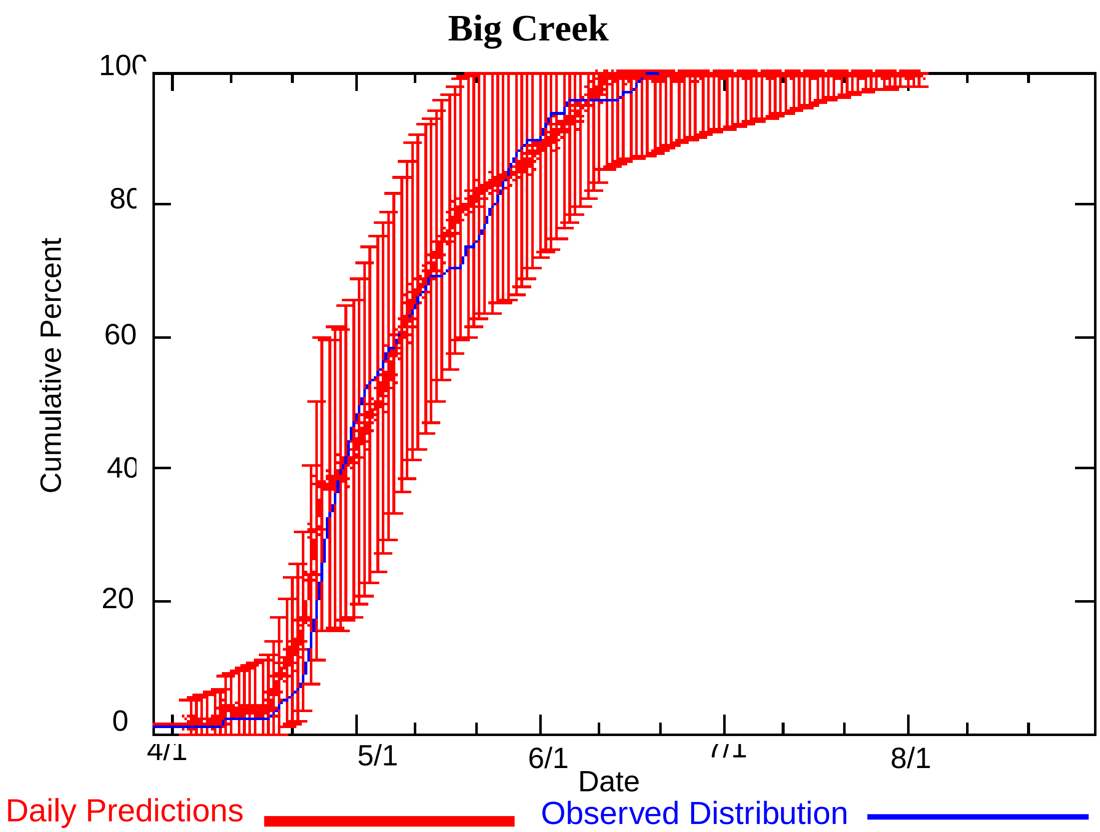
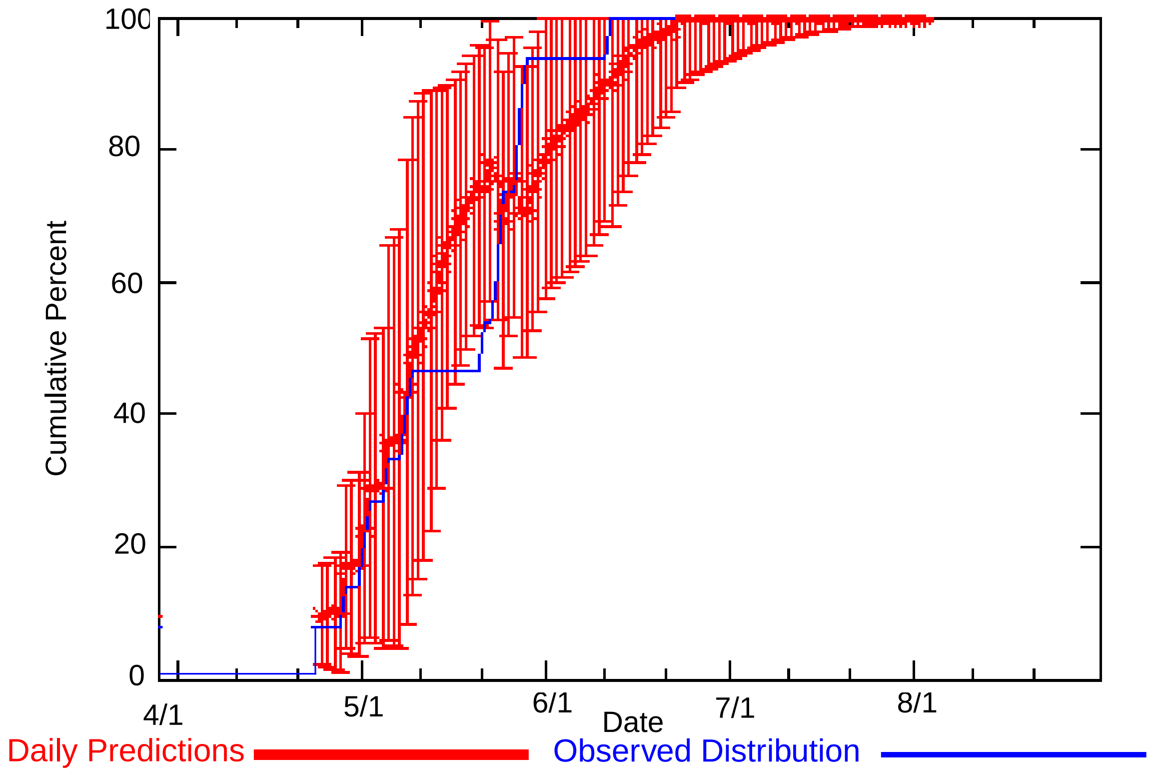


Figure A2: Cape Horn Creek and Catherine Creek Daily Predictions.

Cape Horn Creek



Catherine Creek

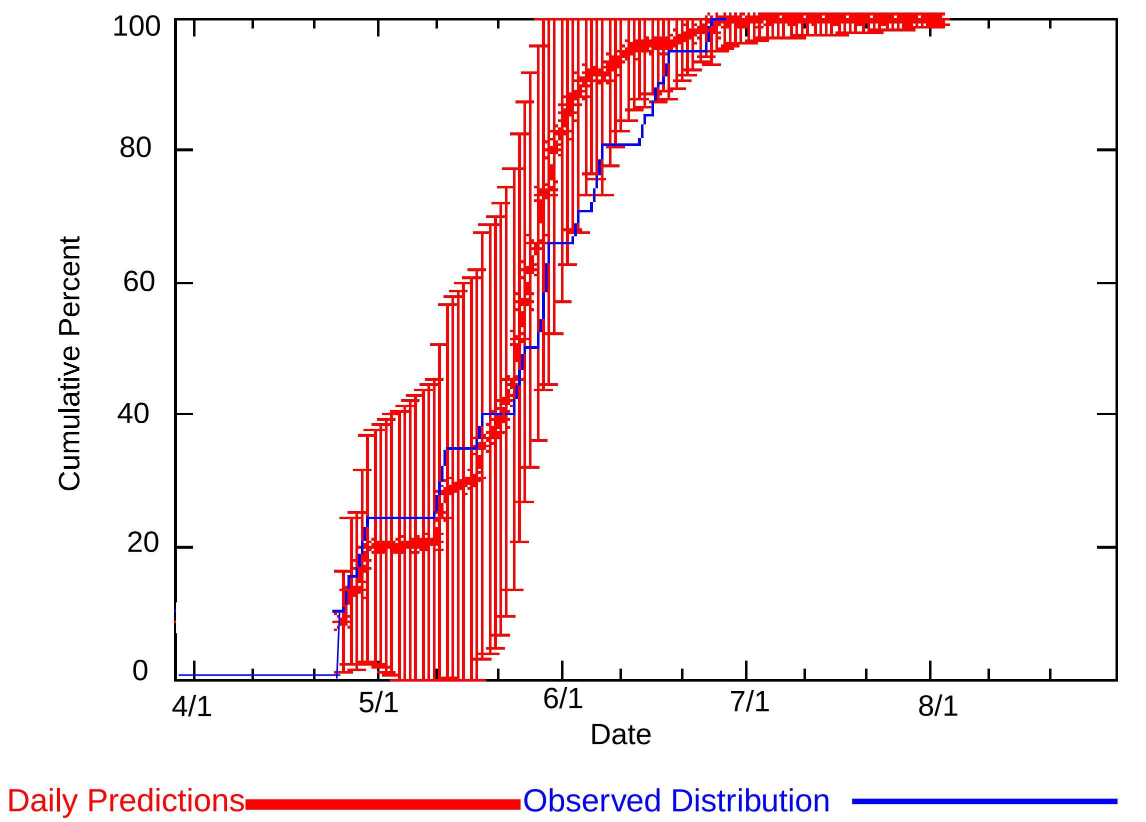
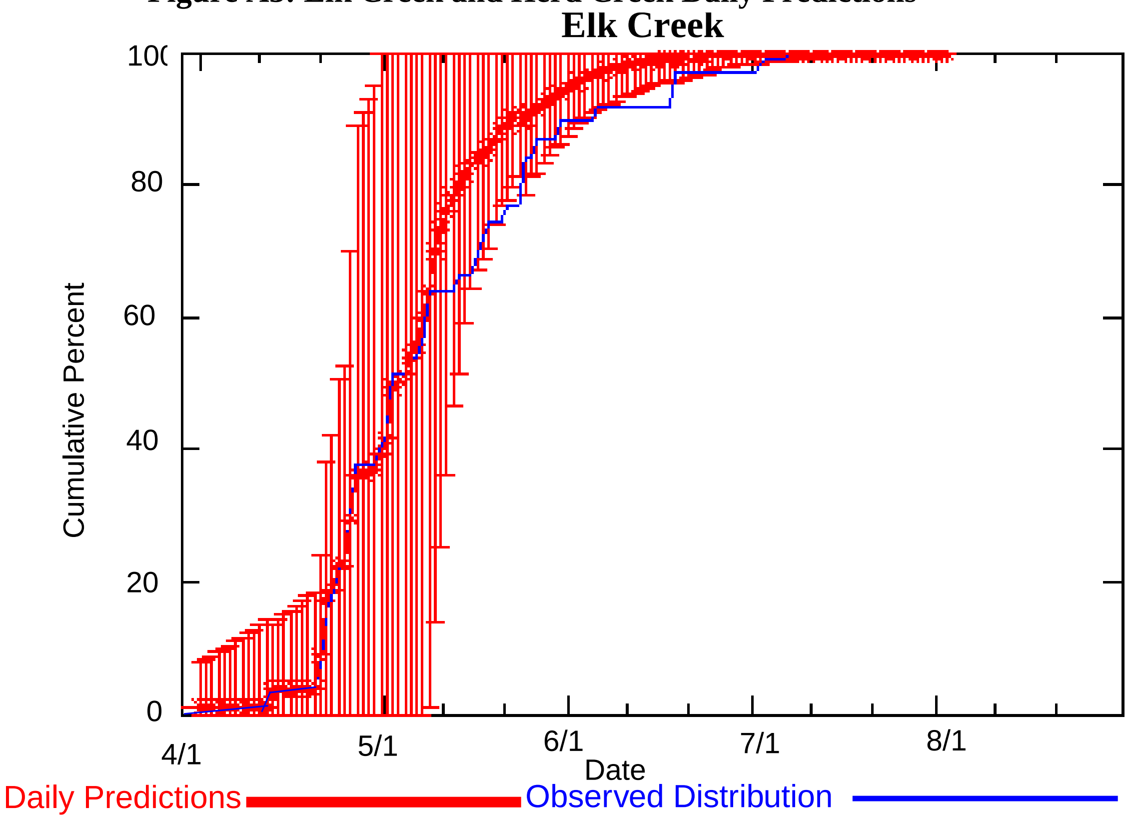


Figure A3: Elk Creek and Herd Creek Daily Predictions



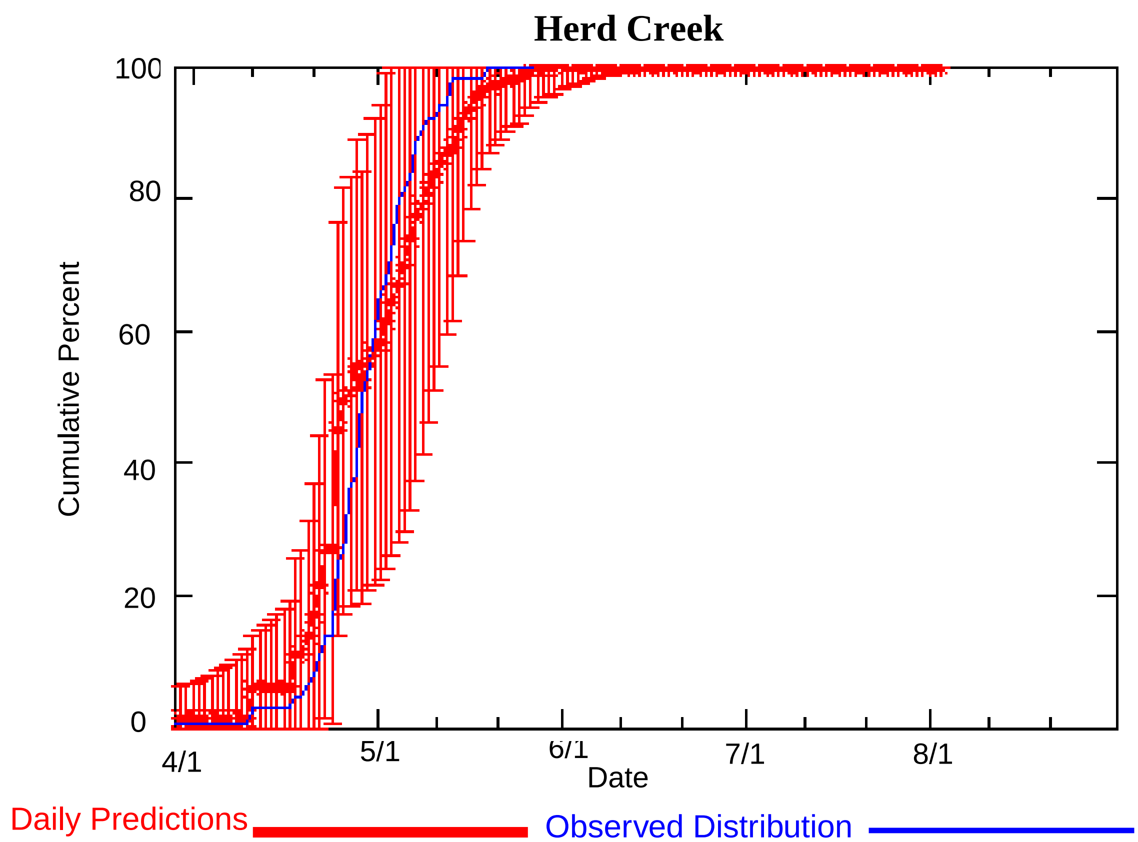
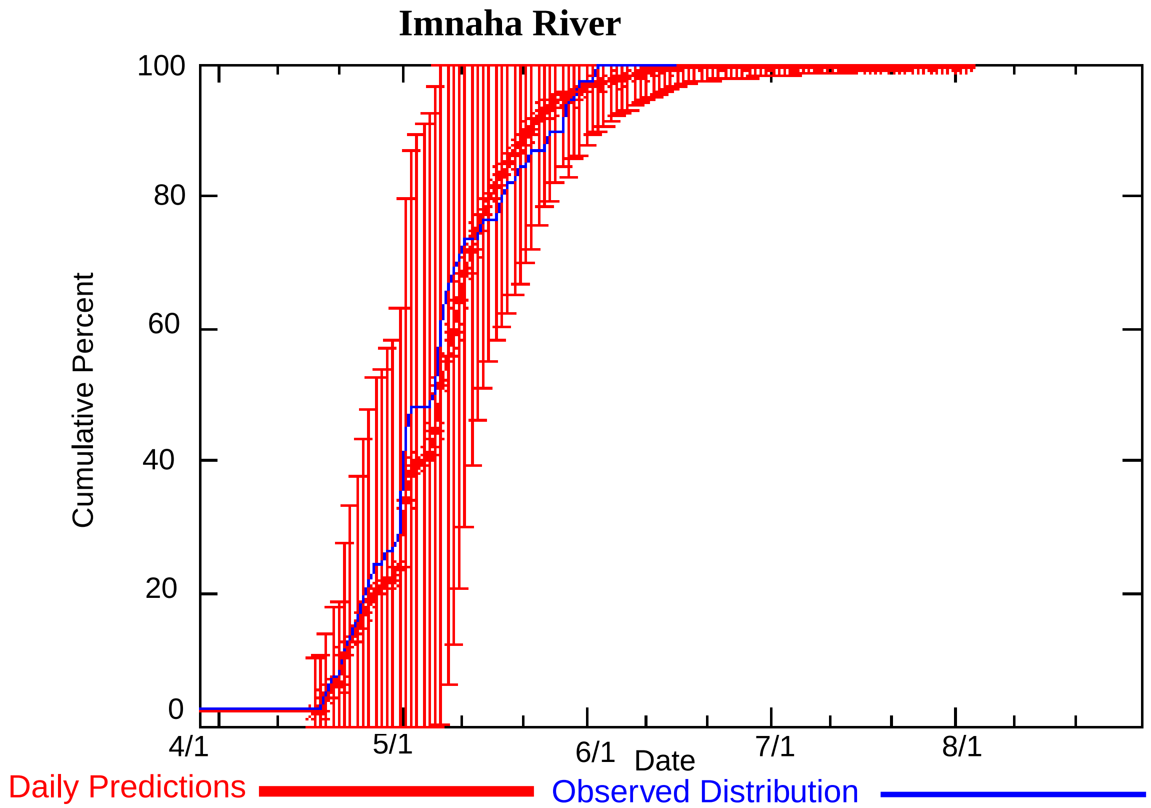


Figure A4: Imnaha River and Lake Creek Daily Predictions.



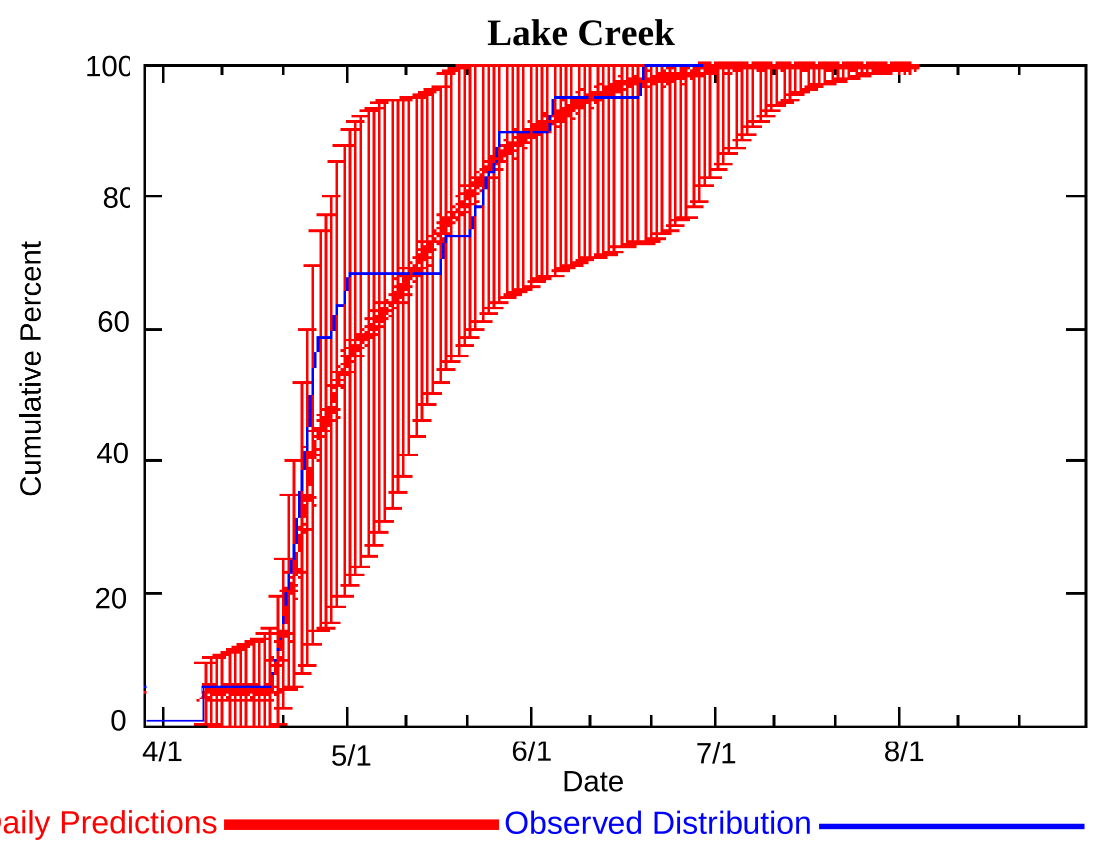
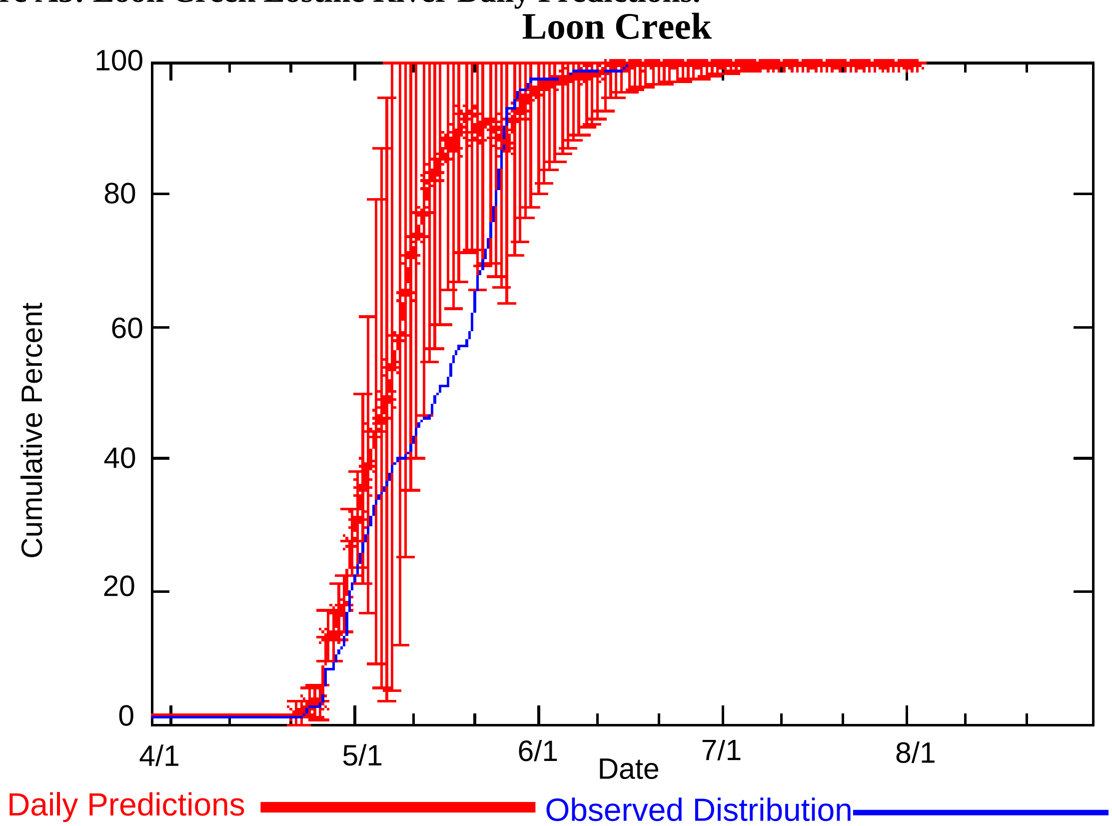


Figure A5: Loon Creek Lostine River Daily Predictions.



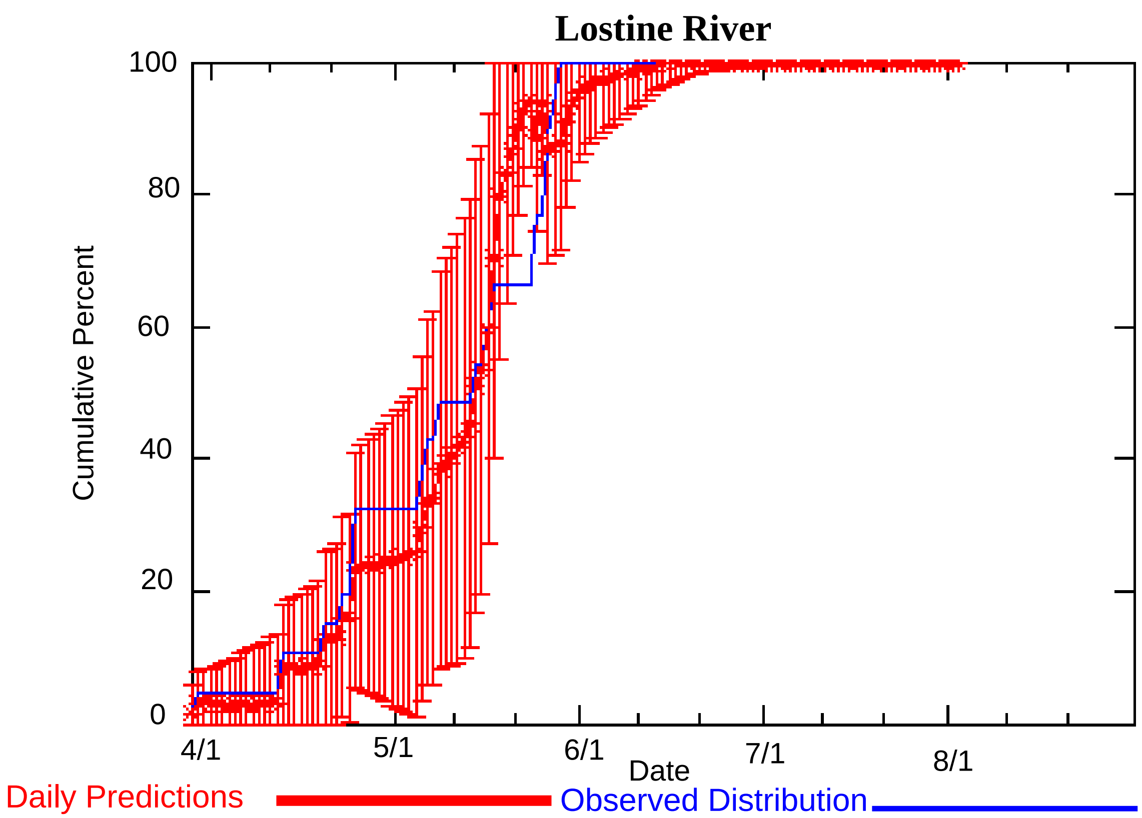
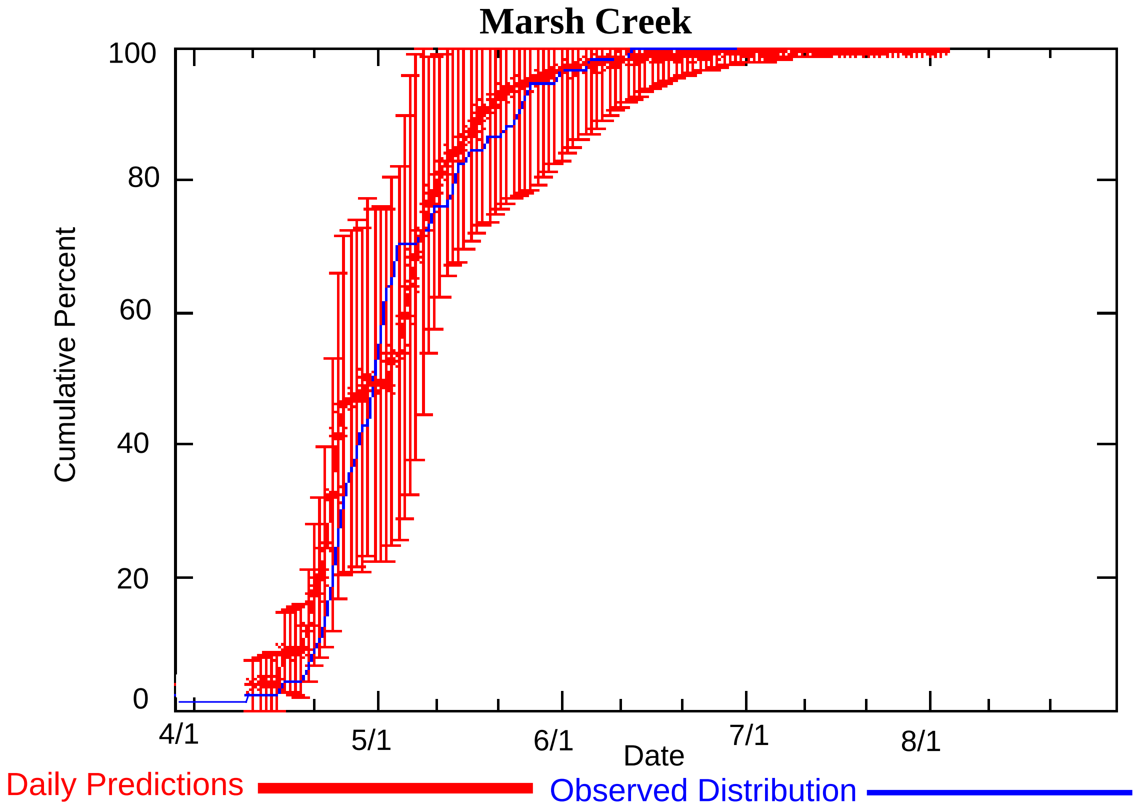


Figure A6: Marsh Creek Minam River Daily Predictions.



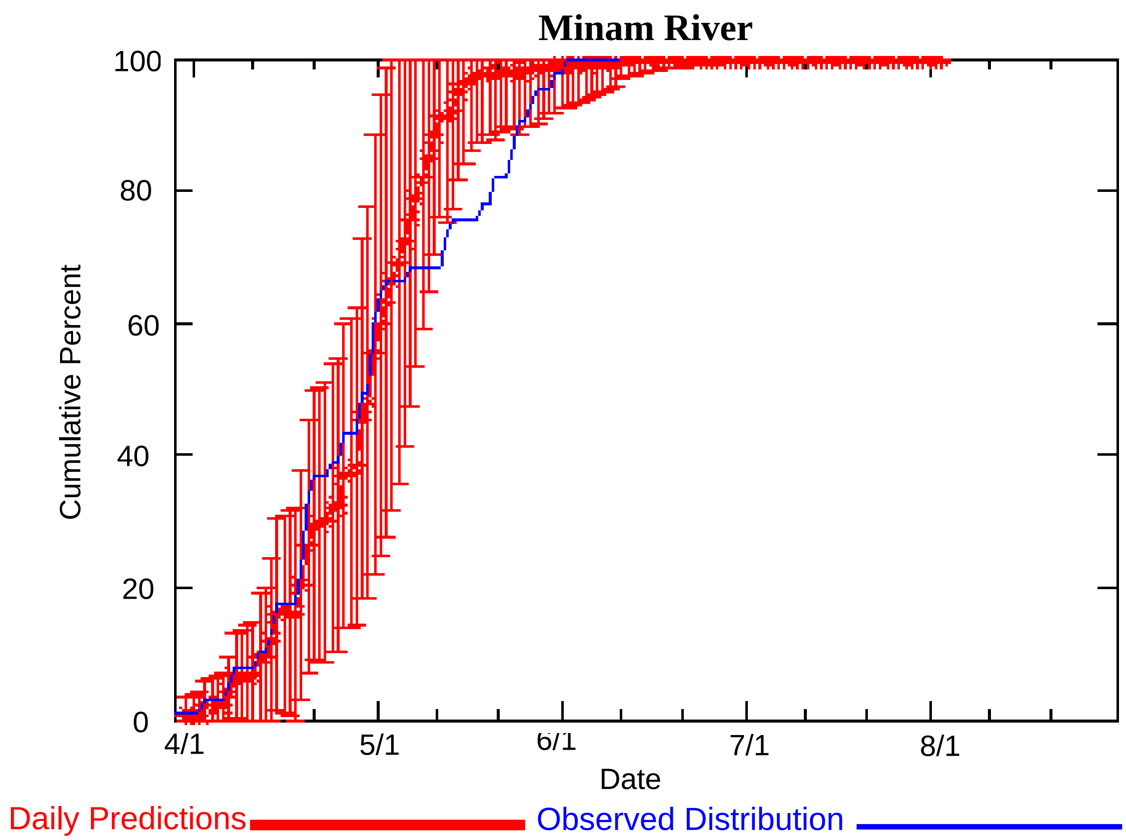
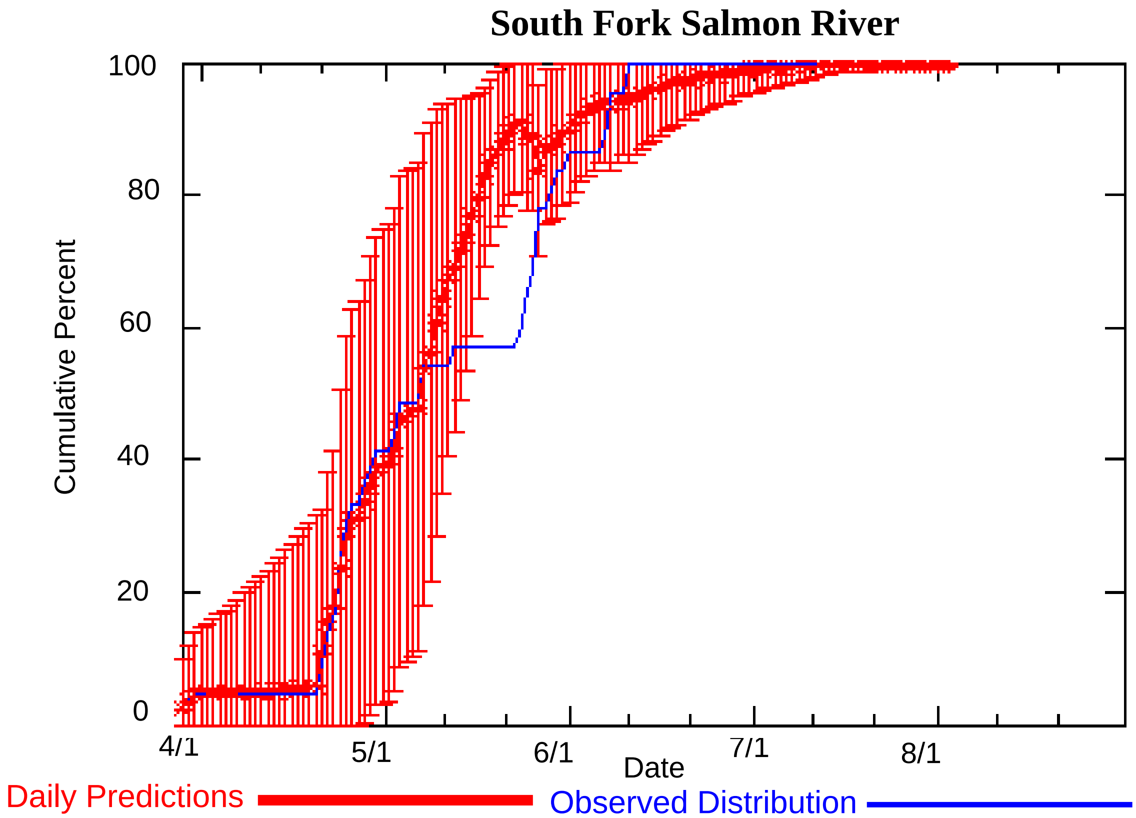


Figure A7: South Fork Salmon River and Secesh River Daily Predictions.



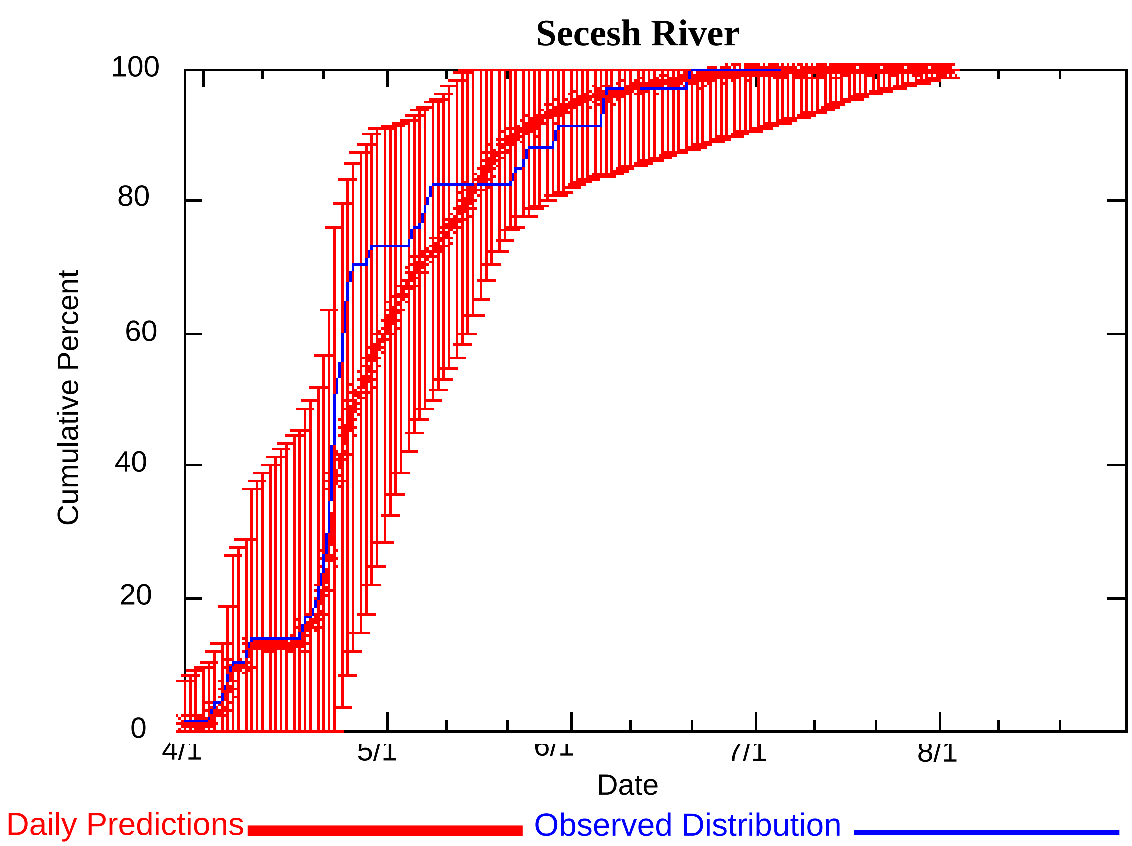
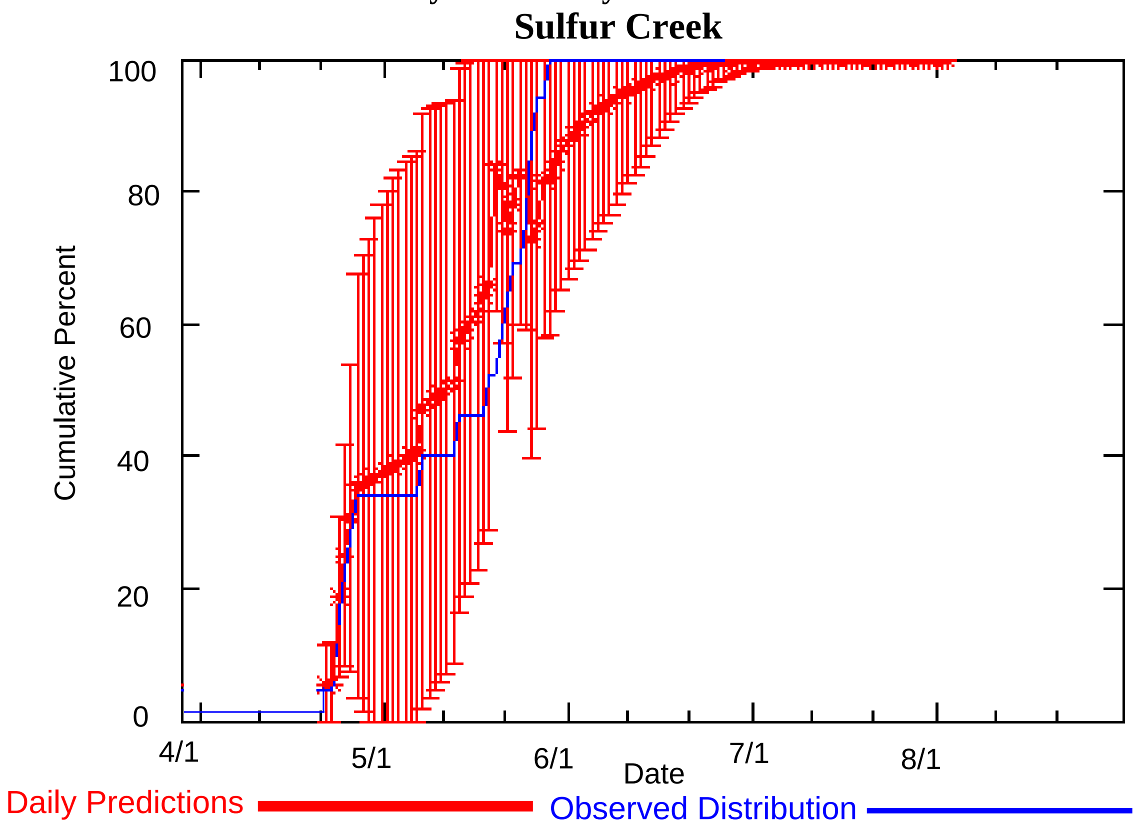


Figure A8: Sulfur Creek and Valley Creek Daily Predictions.



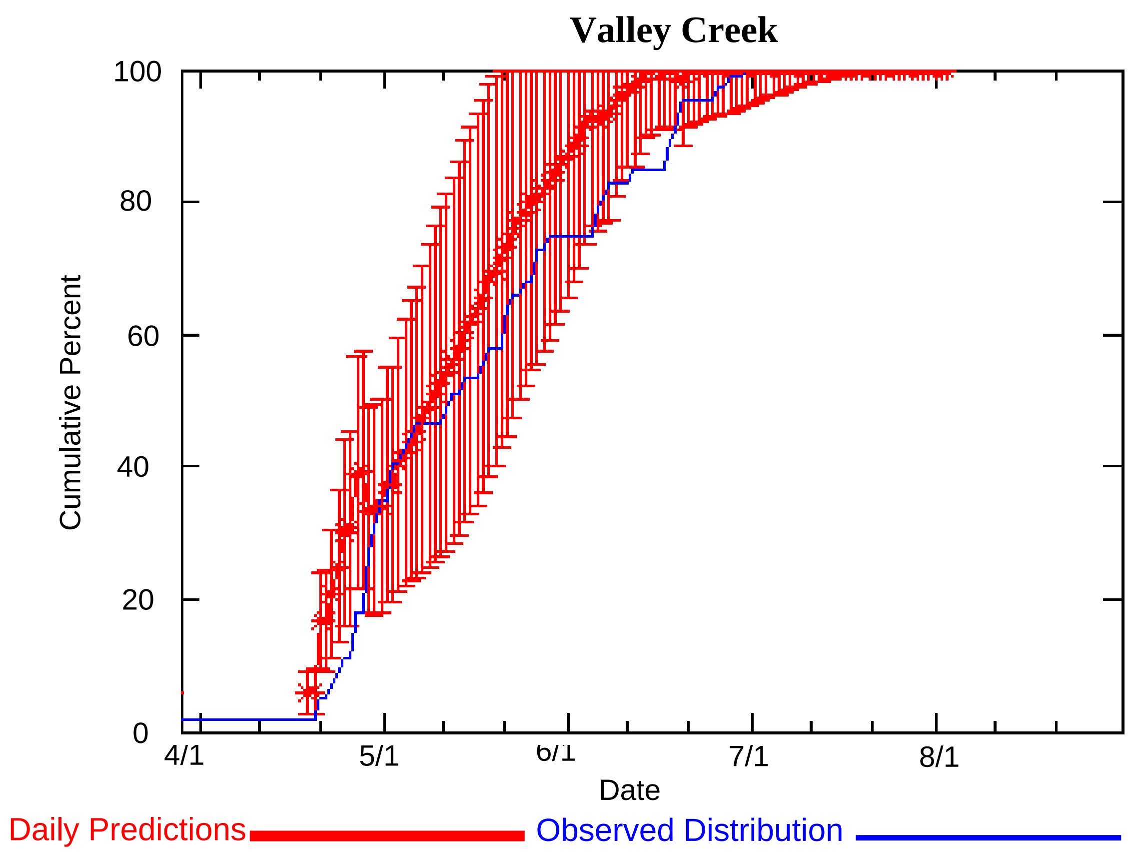
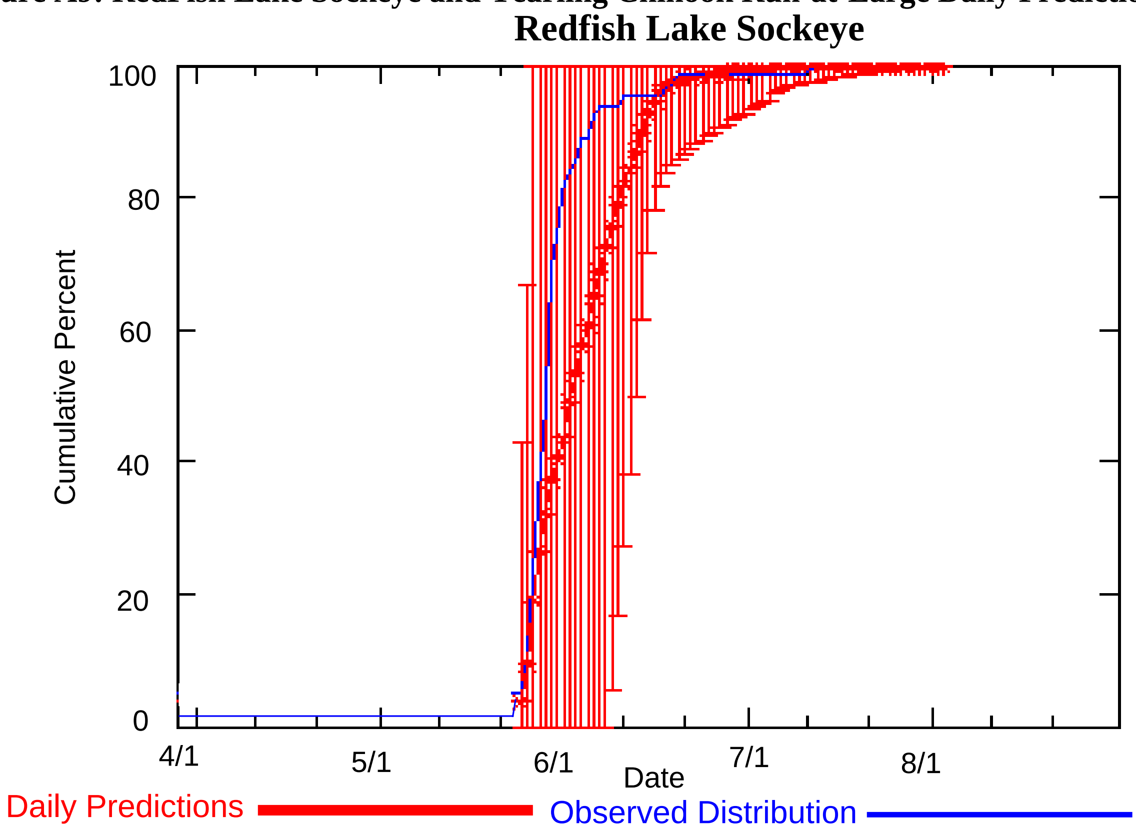


Figure A9: RedFish Lake Sockeye and Yearling Chinook Run-at-Large Daily Predictions.



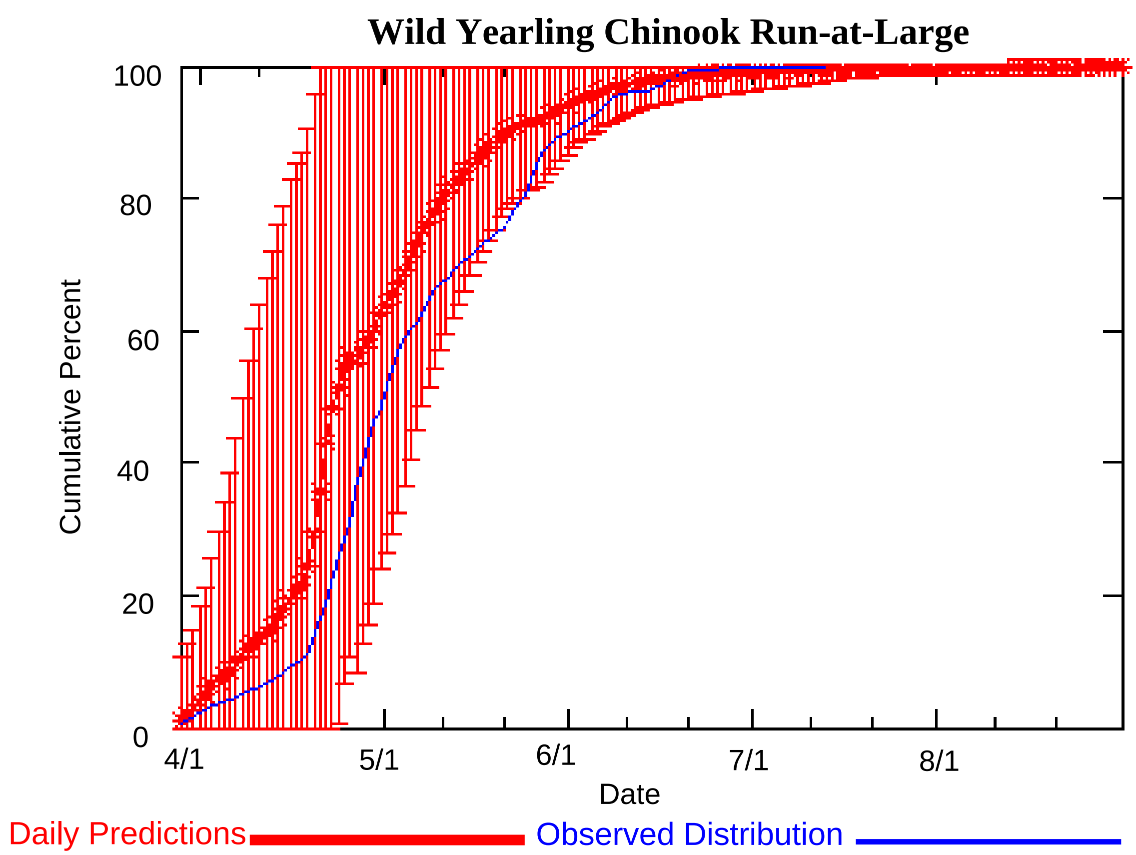
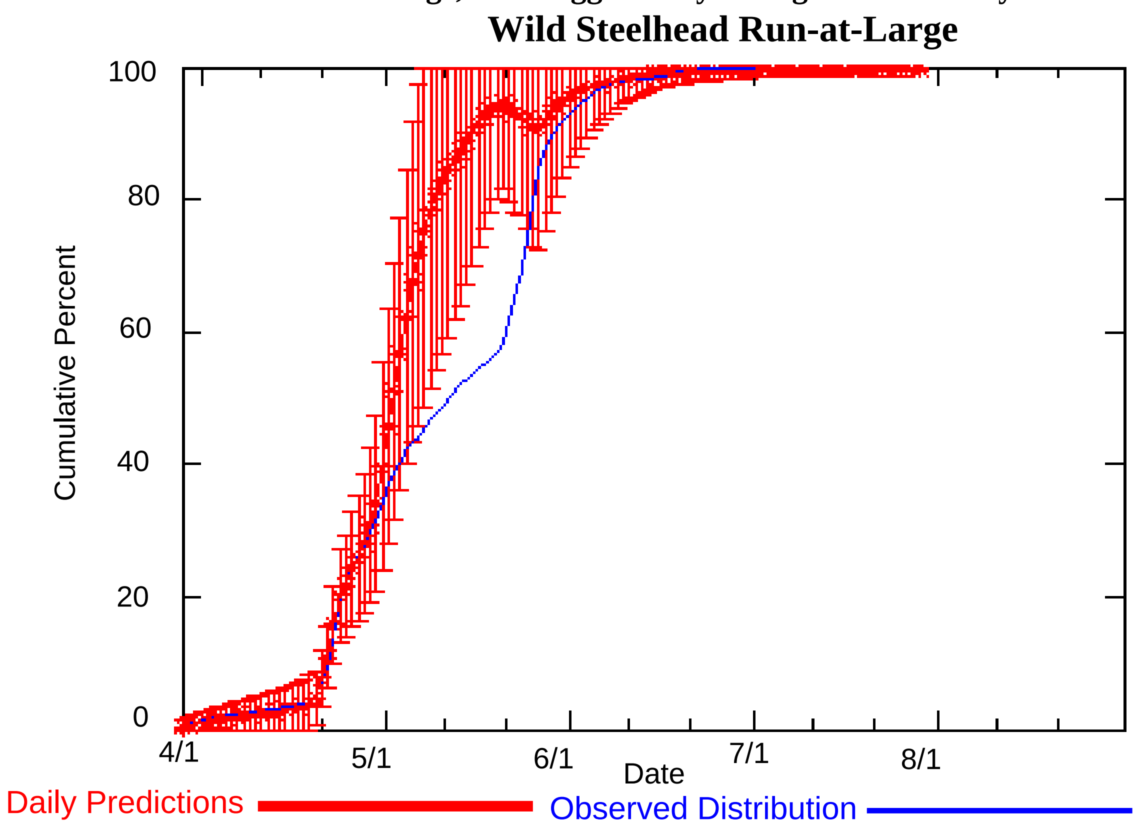
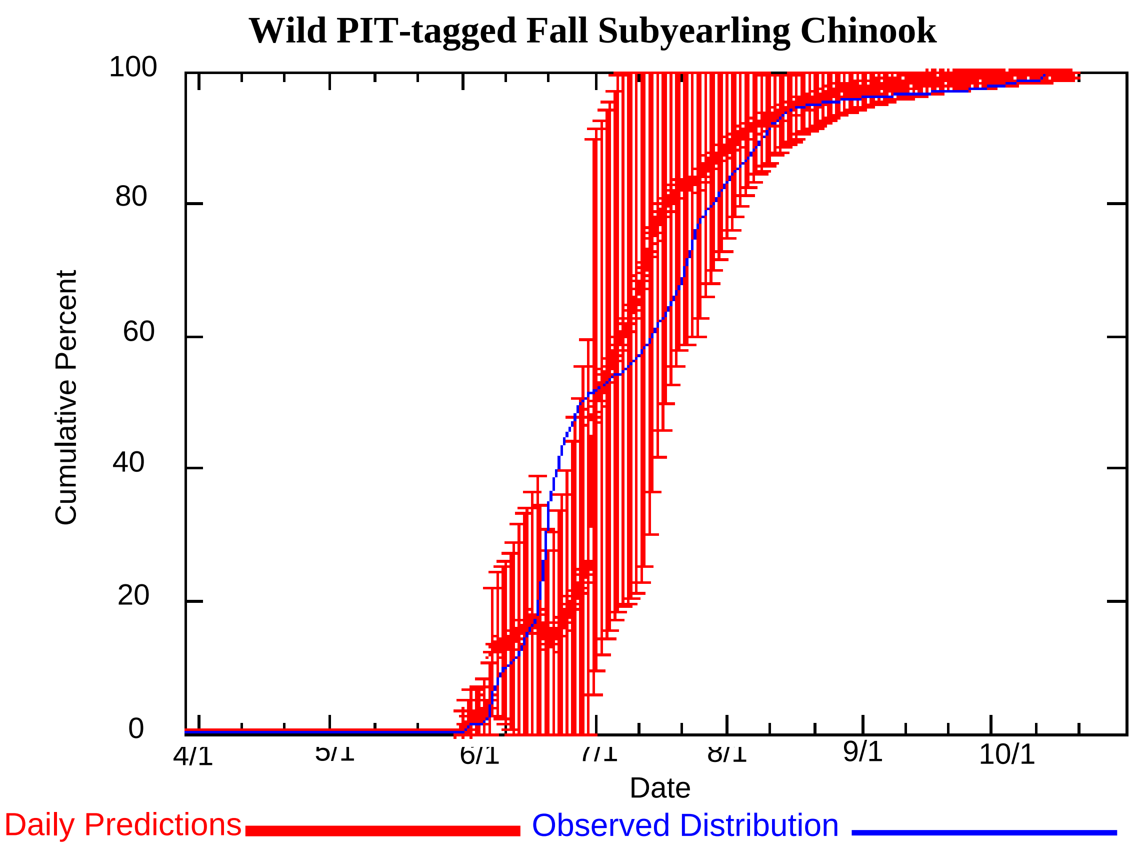


Figure A10: Steelhead Run-at-Large, PIT-tagged Subyearling Chinook Daily Predictions.





Appendix B

Historical timing plots and dates of passage at Lower Granite Dam (from PIT-tag data) for the individual wild yearling chinook release sites tracked by program RealTime during the 1999 outmigration season, for the wild subyearling chinook, yearling chinook, and steelhead runs-of-the-year, and for hatchery-reared Redfish Lake sockeye.

Figure B1: Historical Bear Valley Creek outmigration distribution at Lower Granite Dam.

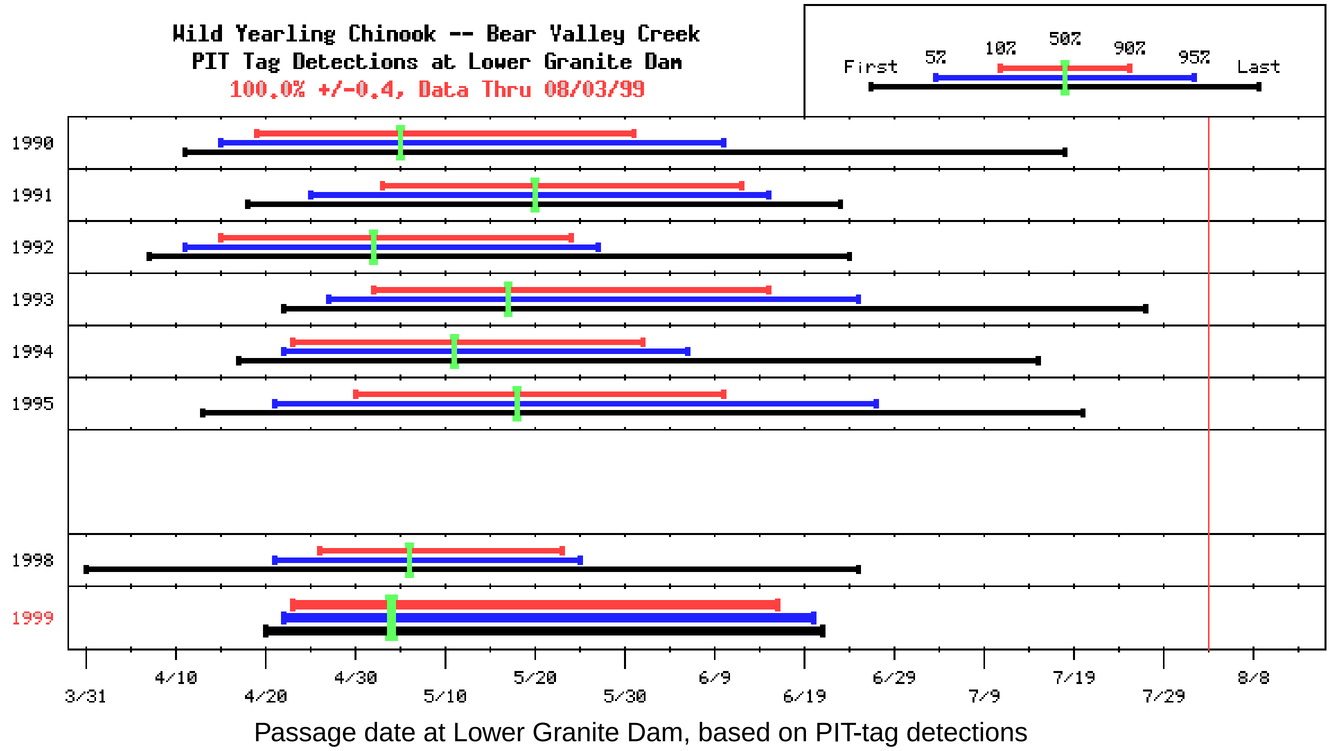


Table B1: Historical Bear Valley Creek outmigration timing characteristics.

Detection Year	Detection Dates							Duration Middle 80% (days)	Parr Released (1)	LGR PIT Detections (2)	Adjusted LGR PIT Detections (3)	% (3)/(1) x 100
	First	5%	10%	50%	90%	95%	Last					
1990	4/11	4/15	4/19	5/06	5/31	6/15	7/18	43	1557	91	91.0	5.8
1991	4/14	4/24	5/01	5/20	6/14	6/22	6/23	41	353	44	44.4	12.6
1992	4/6	4/8	4/10	4/21	5/3	5/7	5/21	40	1044	69	69.0	6.6
1993	4/15	4/22	4/25	5/15	5/29	6/3	6/23	45	1017	67	105.1	10.3
1994	4/2	4/15	4/18	4/23	5/12	5/31	8/11	40	860	85	115.4	13.4
1995	4/10	4/11	4/14	5/9	6/3	6/4	7/7	42	1460	74	101.7	7.0
1998	3/31	4/20	4/25	5/04	5/23	5/25	6/25	28	427	59	113.5	26.6
1999	4/20	4/22	4/23	5/04	6/16	6/20	6/21	55	820	39	92.2	11.2

(1) Parr PIT-tagged and released during the summer of the year prior to detection year.
(2) PIT detections of yearling Age 1 chinook smolts at Lower Granite Dam.
(3) Spill-adjusted (Appendix C) PIT detections of yearling Age 1 chinook smolts at Lower Granite Dam.

Figure B2. Historical Big Creek outmigration distribution at Lower Granite Dam.

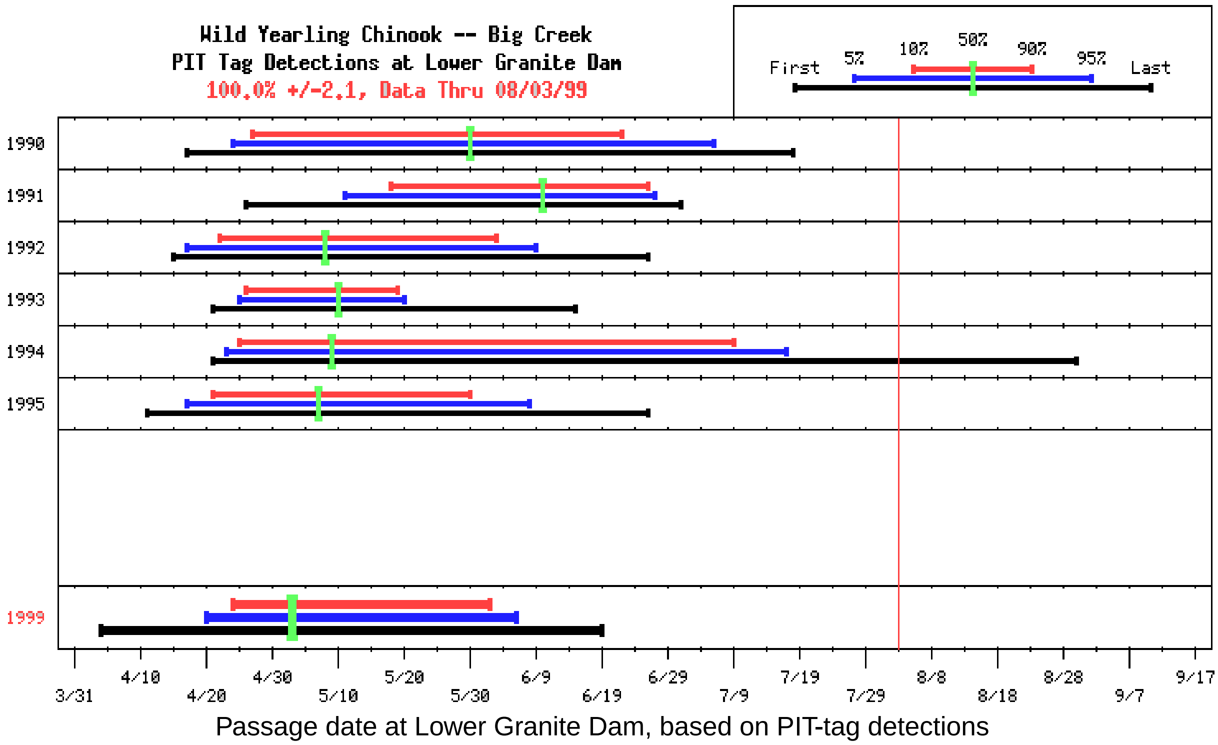


Table B2: Historical Big Creek outmigration timing characteristics.

Detection Year	Detection Dates							Duration Middle 80% (days)	Parr Released (1)	LGR PIT Detections (2)	Adjusted LGR PIT Detections (3)	% (3)/(1) x 100
	First	5%	10%	50%	90%	95%	Last					
1990	4/17	4/24	4/27	5/30	6/22	7/06	7/18	57	2035	145	145.0	7.1
1991	4/26	5/11	5/18	6/10	6/26	6/27	7/01	40	727	67	67.8	9.3
1992	4/15	4/17	4/22	5/08	6/03	6/09	6/26	43	1008	57	57.0	5.7
1993	4/21	4/25	4/26	5/10	5/19	5/20	6/15	24	733	65	84.7	11.6
1994	4/21	4/23	4/25	5/09	7/09	7/17	8/30	76	722	56	68.7	9.5
1995	4/11	4/17	4/21	5/07	5/30	6/08	6/26	40	1484	164	220.2	14.8
1999	4/04	4/20	4/24	5/03	6/02	6/06	6/19	40	1427	96	232.0	16.3

(1) Parr PIT-tagged and released during the summer of the year prior to detection year.
(2) PIT detections of yearling Age 1 chinook smolts at Lower Granite Dam.
(3) Spill-adjusted (Appendix C) PIT detections of yearling Age 1 chinook smolts at Lower Granite Dam.

Figure B3: Historical Cape Horn Creek outmigration distribution at Lower Granite Dam.

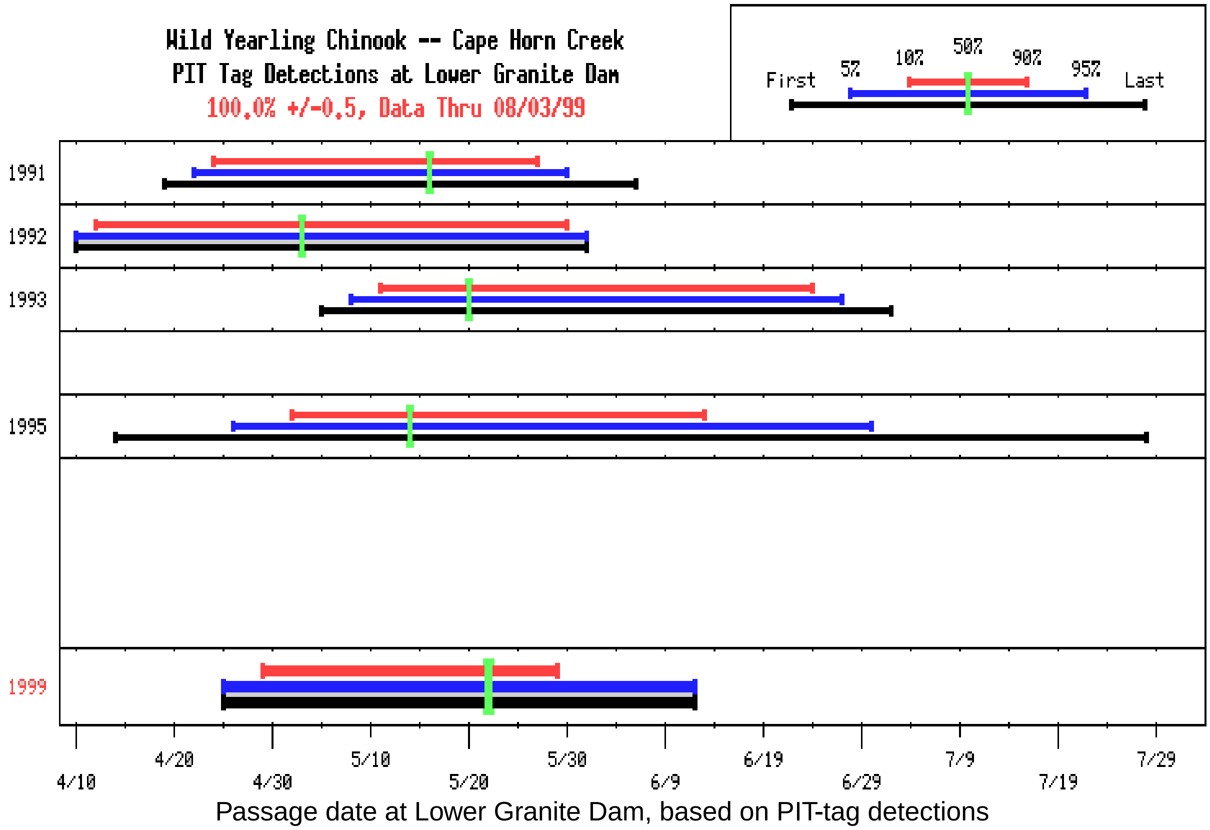


Table B3: Historical Cape Horn Creek outmigration timing characteristics.

Detection Year	Detection Dates							Duration Middle 80% (days)	Parr Released (1)	LGR PIT Detections (2)	Adjusted LGR PIT Detections (3)	% (3)/(1) x 100
	First	5%	10%	50%	90%	95%	Last					
1991	4/19	4/22	4/24	5/16	5/27	5/30	6/06	34	164	25	25.4	15.5
1992	4/10	4/10	4/12	5/03	5/30	6/01	6/01	49	209	19	19.0	9.1
1993	5/05	5/08	5/11	5/20	6/24	6/27	7/02	45	206	22	34.4	16.7
1995	4/14	4/26	5/02	5/14	6/13	6/30	7/28	43	1445	84	120.4	8.3
1999	4/25	4/25	4/29	5/22	5/29	6/12	6/12	31	270	15	35.8	13.3

(1) Parr PIT-tagged and released during the summer of the year prior to detection year.
(2) PIT detections of yearling Age 1 chinook smolts at Lower Granite Dam.
(3) Spill-adjusted (Appendix C) PIT detections of yearling Age 1 chinook smolts at Lower Granite Dam.

Figure B4: Historical Catherine Creek outmigration distribution at Lower Granite Dam.

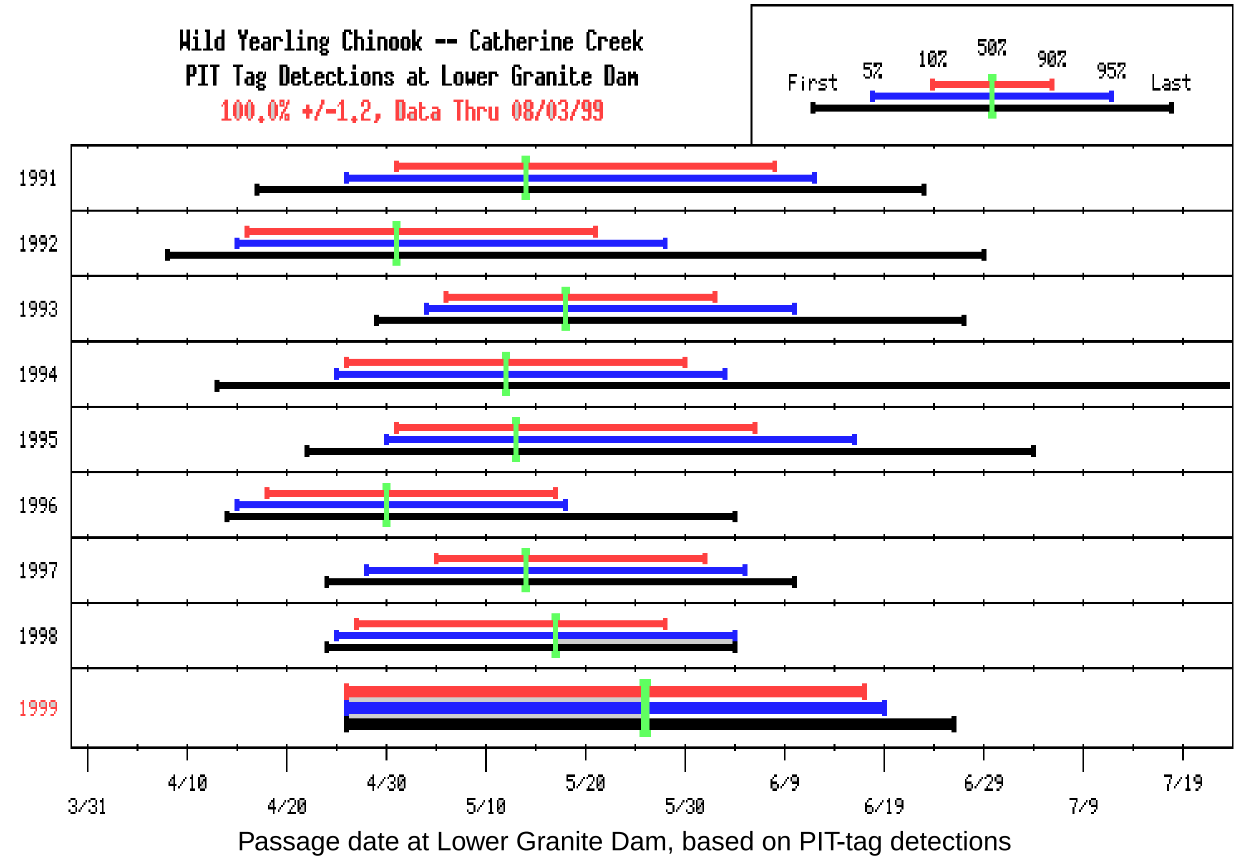


Table B4: Historical Catherine Creek outmigration timing characteristics.

Detection Year	Detection Dates							Duration Middle 80% (days)	Parr Released (1)	LGR PIT Detections (2)	Adjusted LGR PIT Detections (3)	% (3)/(1) x 100
	First	5%	10%	50%	90%	95%	Last					
1991	4/17	4/26	5/1	5/14	6/8	6/12	6/23	39	1014	77	77.8	7.7
1992	4/8	4/15	4/16	5/1	5/21	5/28	6/29	36	940	67	67.0	7.1
1993	4/29	5/4	5/6	5/18	6/2	6/10	6/27	28	1108	102	158.2	14.3
1994	4/13	4/25	4/26	5/12	5/30	6/3	7/26	35	1000	76	110.5	11.0
1995	4/22	4/30	5/1	5/13	6/6	6/16	7/4	37	2061	202	268.1	13.0
1996	4/14	4/15	4/18	4/30	5/17	5/18	6/4	30	1682	116	257.0	15.3
1997	4/24	4/28	5/05	5/14	6/01	6/05	6/10	28	585	51	120.2	20.6
1998	4/24	4/25	4/26	5/12	5/27	6/04	6/04	32	495	43	91.3	18.4
1999	4/26	4/26	4/26	5/26	6/17	6/19	6/26	53	504	20	49.6	9.8

(1) Parr PIT-tagged and released during the summer of the year prior to detection year.
(2) PIT detections of yearling Age 1 chinook smolts at Lower Granite Dam.
(3) Spill-adjusted (Appendix C) PIT detections of yearling Age 1 chinook smolts at Lower Granite Dam.

Figure B5: Historical Elk Creek outmigration distribution at Lower Granite Dam.

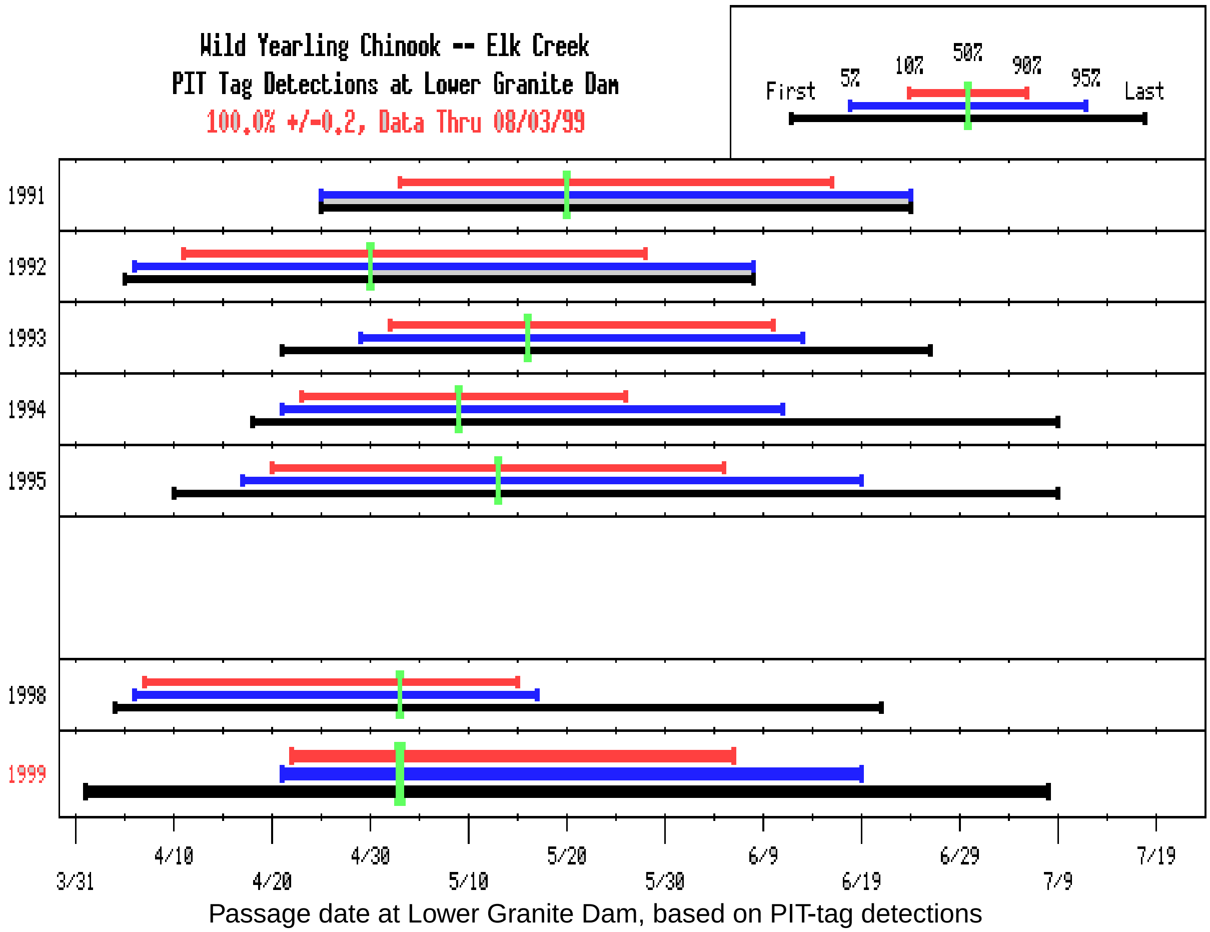


Table B5: Historical Elk Creek outmigration timing characteristics.

Detection Year	Detection Dates							Duration Middle 80% (days)	Parr Released (1)	LGR PIT Detections (2)	Adjusted LGR PIT Detections (3)	% (3)/(1) x 100
	First	5%	10%	50%	90%	95%	Last					
1991	4/25	4/25	4/25	5/21	6/19	6/24	6/24	45	248	32	32.8	13.2
1992	4/05	4/06	4/11	5/01	5/28	6/08	6/08	48	462	36	36.0	7.8
1993	4/21	4/27	5/02	5/16	6/13	6/21	6/26	40	628	42	63.8	10.2
1994	4/18	4/21	4/23	5/10	6/11	6/15	7/09	34	999	76	96.4	9.7
1995	4/11	4/15	4/18	5/14	6/11	6/26	7/09	47	1514	75	100.4	6.6
1998	4/04	4/06	4/07	5/02	5/12	5/17	6/21	39	246	57	104.0	42.3
1999	4/01	4/21	4/22	5/03	6/06	6/19	7/08	46	700	44	99.1	14.2

(1) Parr PIT-tagged and released during the summer of the year prior to detection year.
(2) PIT detections of yearling Age 1 chinook smolts at Lower Granite Dam.
(3) Spill-adjusted (Appendix C) PIT detections of yearling Age 1 chinook smolts at Lower Granite Dam.

Figure B6: Historical Herd Creek outmigration distribution at Lower Granite Dam.

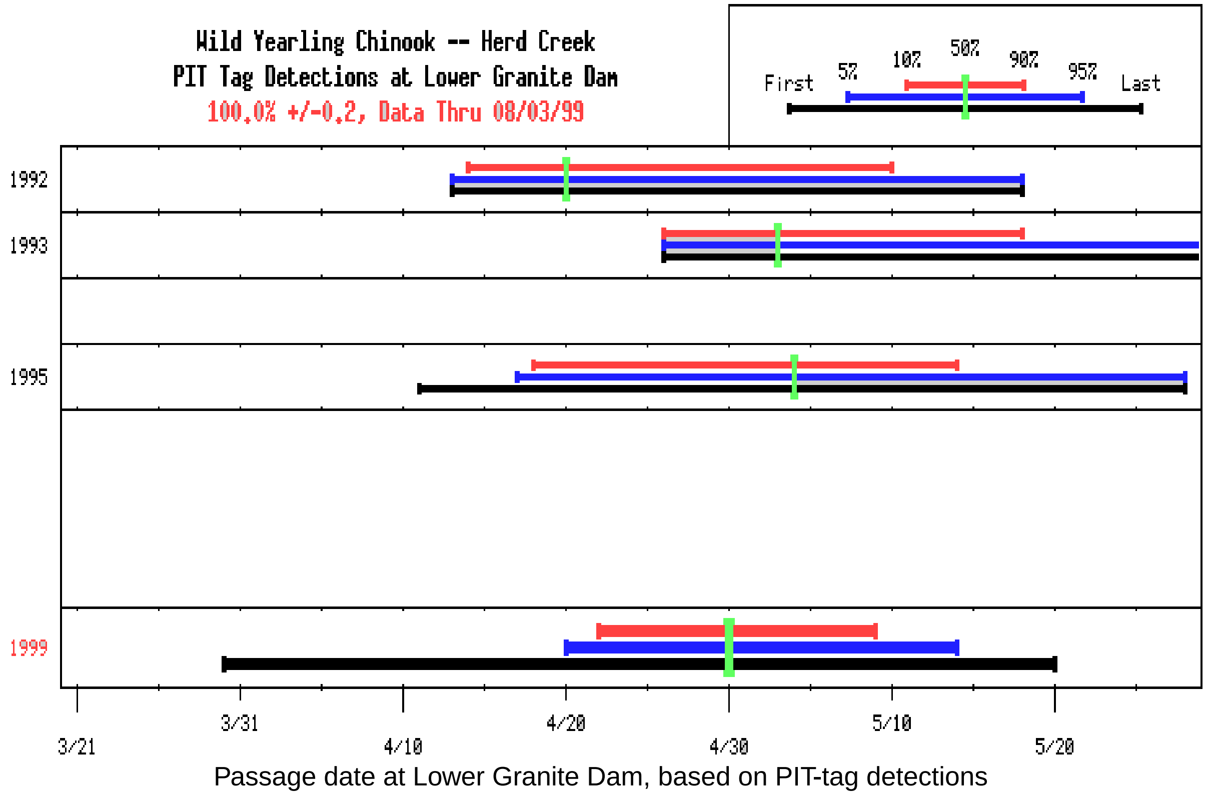


Table B6: Historical Herd Creek outmigration timing characteristics.

Detection Year	Detection Dates							Duration Middle 80% (days)	Parr Released (1)	LGR PIT Detections (2)	Adjusted LGR PIT Detections (3)	% (3)/(1) x 100
	First	5%	10%	50%	90%	95%	Last					
1992	4/13	4/13	4/14	4/20	5/10	5/18	5/18	27	312	17	17.0	5.4
1993	4/26	4/26	4/26	5/03	5/18	5/31	5/31	23	224	16	19.5	8.7
1995	4/11	4/17	4/18	5/04	5/14	5/28	5/28	27	534	36	46.2	8.7
1999	3/30	4/20	4/22	4/30	5/09	5/14	5/20	18	959	56	131.6	13.7

(1) Parr PIT-tagged and released during the summer of the year prior to detection year.
(2) PIT detections of yearling Age 1 chinook smolts at Lower Granite Dam.
(3) Spill-adjusted (Appendix C) PIT detections of yearling Age 1 chinook smolts at Lower Granite Dam.

Figure B7: Historical Imnaha River outmigration distribution at Lower Granite Dam.

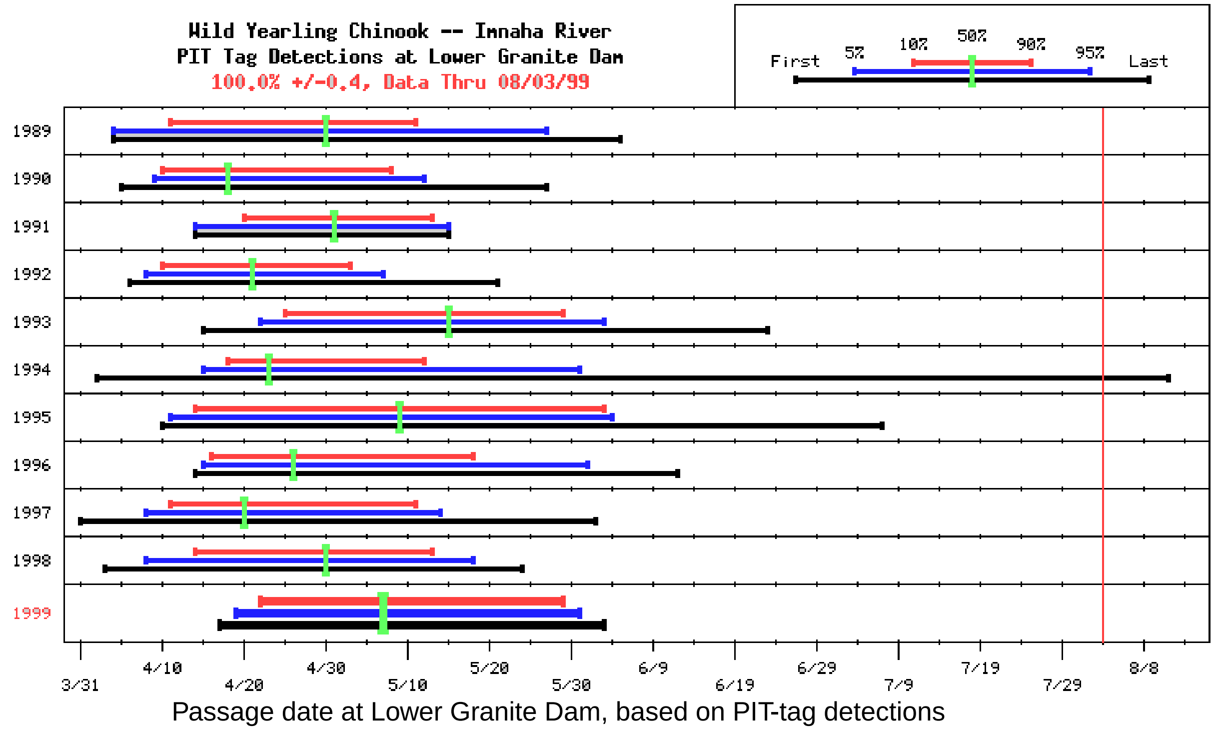


Table B7: Historical Imnaha River outmigration timing characteristics.

Detection Year	Detection Dates							Duration Middle 80% (days)	Parr Released (1)	LGR PIT Detections (2)	Adjusted LGR PIT Detections (3)	% (3)/(1) x 100
	First	5%	10%	50%	90%	95%	Last					
1989	4/4	4/4	4/11	4/30	5/11	5/27	6/5	31	1213	73	73.0	6.0
1990	4/5	4/9	4/10	4/18	5/8	5/12	5/27	29	2005	161	161.0	8.0
1991	4/14	4/14	4/20	5/1	5/13	5/15	5/15	24	334	18	18.0	5.4
1992	4/6	4/8	4/10	4/21	5/3	5/7	5/21	24	759	73	73.0	9.6
1993	4/15	4/22	4/25	5/15	5/29	6/3	6/23	35	1003	63	88.3	8.8
1994	4/2	4/15	4/18	4/23	5/12	5/31	8/11	25	1753	205	218.2	12.4
1995	4/10	4/11	4/14	5/9	6/3	6/4	7/7	51	999	40	50.9	5.1
1996	4/14	4/15	4/16	4/26	5/18	6/1	6/12	33	997	97	230.6	23.1
1997	3/31	4/08	4/11	4/20	5/11	5/14	6/02	31	1017	98	191.1	18.8
1998	4/03	4/08	4/14	4/28	5/13	5/16	5/24	30	1010	159	283.5	28.1
1999	4/17	4/19	4/22	5/07	5/29	5/31	6/03	38	1009	40	95.3	9.4

(1) Parr PIT-tagged and released during the summer of the year prior to detection year.
(2) PIT detections of yearling Age 1 chinook smolts at Lower Granite Dam.
(3) Spill-adjusted (Appendix C) PIT detections of yearling Age 1 chinook smolts at Lower Granite Dam.

Figure B8: Historical Lake Creek outmigration distribution at Lower Granite Dam.

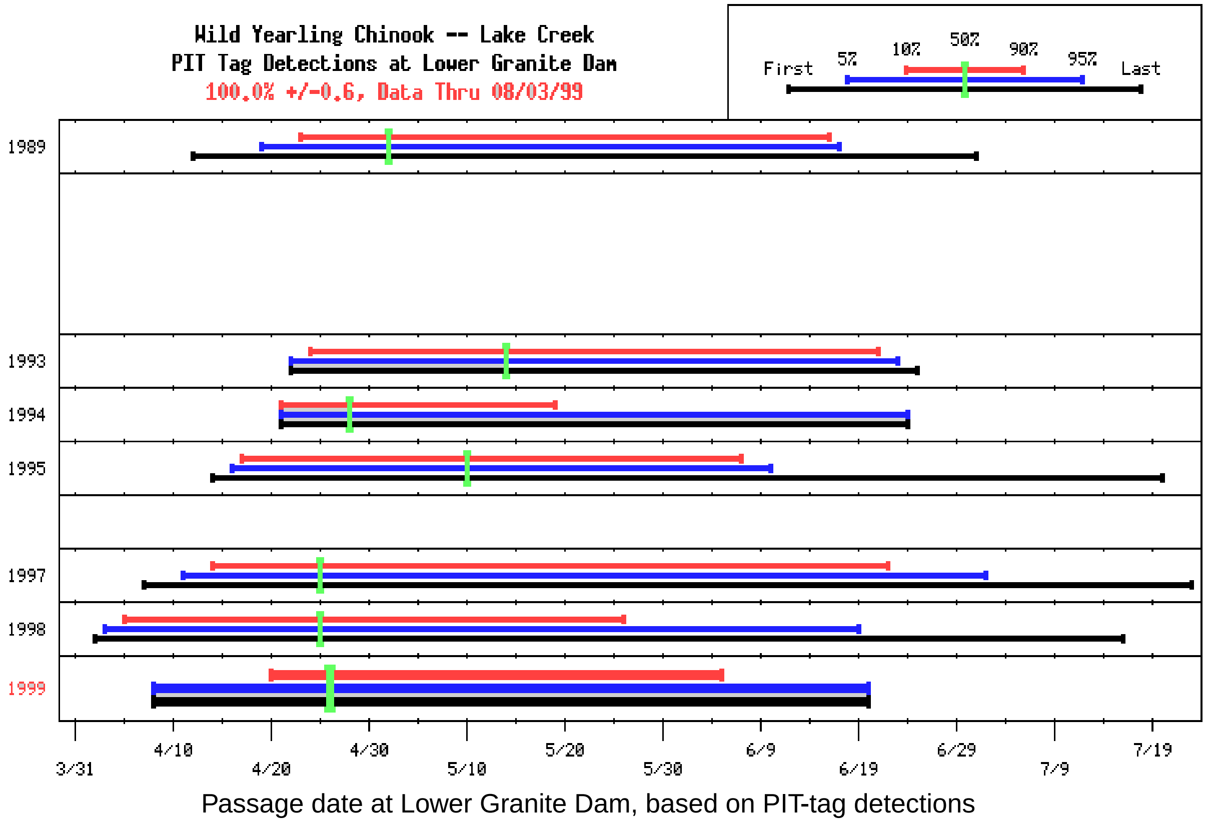


Table B8: Historical Lake Creek outmigration timing characteristics.

Detection Year	Detection Dates							Duration Middle 80% (days)	Parr Released (1)	LGR PIT Detections (2)	Adjusted LGR PIT Detections (3)	% (3)/(1) x 100
	First	5%	10%	50%	90%	95%	Last					
1989	4/12	4/19	4/23	5/02	6/16	6/17	7/01	55	660	51	51.0	7.7
1993	4/22	4/22	4/24	5/14	6/21	6/23	6/25	59	255	27	31.1	12.2
1994	4/21	4/21	4/21	4/28	5/19	6/24	6/24	29	252	17	19.8	7.9
1995	4/14	4/16	4/17	5/10	6/07	6/10	7/20	52	406	25	33.2	8.2
1997	4/07	4/11	4/14	4/25	6/22	7/02	7/23	70	400	21	40.8	10.2
1998	4/02	4/03	4/05	4/25	6/25	7/07	7/16	52	418	48	80.3	19.2
1999	4/08	4/08	4/20	4/26	6/05	6/20	6/20	47	545	20	47.1	8.7

(1) Parr PIT-tagged and released during the summer of the year prior to detection year.
(2) PIT detections of yearling Age 1 chinook smolts at Lower Granite Dam.
(3) Spill-adjusted (Appendix C) PIT detections of yearling Age 1 chinook smolts at Lower Granite Dam.

Figure B9: Historical Loon Creek outmigration distribution at Lower Granite Dam.

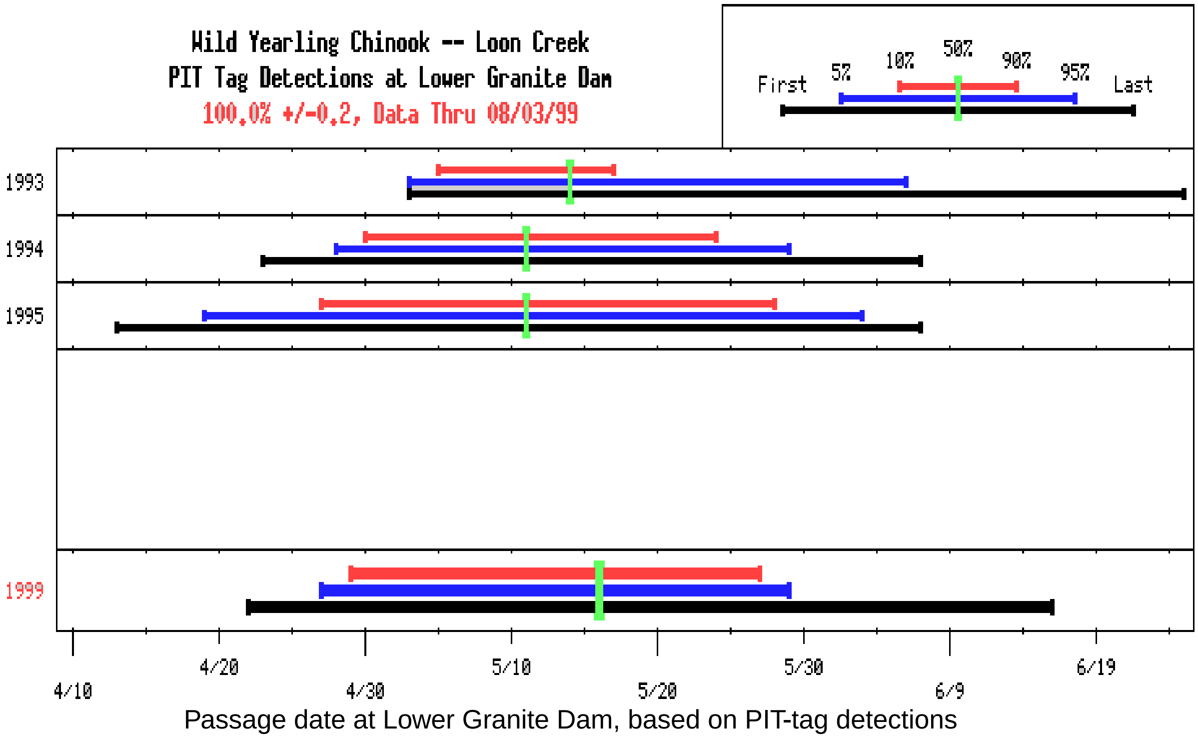
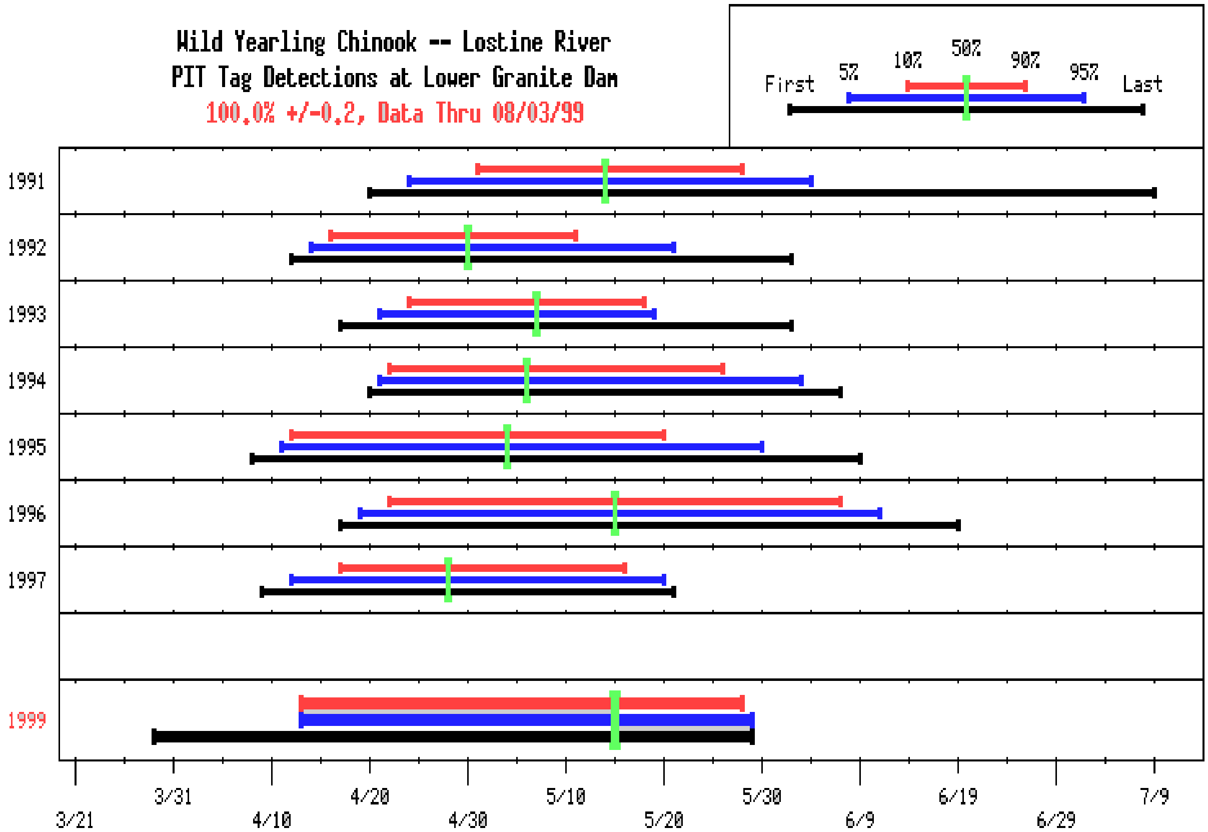


Table B9: Historical Loon Creek outmigration timing characteristics.

Detection Year	Detection Dates							Duration Middle 80% (days)	Parr Released (1)	LGR PIT Detections (2)	Adjusted LGR PIT Detections (3)	% (3)/(1) x 100
	First	5%	10%	50%	90%	95%	Last					
1993	5/03	5/03	5/05	5/14	5/17	6/06	6/25	13	261	24	35.3	13.5
1994	4/23	4/28	4/30	5/11	5/24	5/29	6/07	25	396	37	50.8	12.8
1995	4/13	4/19	4/27	5/11	5/28	6/03	6/07	32	964	83	117.8	12.2
1999	4/22	4/27	4/29	5/16	5/27	5/29	6/16	29	1029	71	173.5	16.9

(1) Parr PIT-tagged and released during the summer of the year prior to detection year.
(2) PIT detections of yearling Age 1 chinook smolts at Lower Granite Dam.
(3) Spill-adjusted (Appendix C) PIT detections of yearling Age 1 chinook smolts at Lower Granite Dam.

Figure B10: Historical Lostine River outmigration distribution at Lower Granite Dam.



Passage date at Lower Granite Dam, based on PIT-tag detections

Table B10: Historical Lostine River outmigration timing characteristics.

Detection Year	Detection Dates							Duration Middle 80% (days)	Parr Released (1)	LGR PIT Detections (2)	Adjusted LGR PIT Detections (3)	% (3)/(1) x 100
	First	5%	10%	50%	90%	95%	Last					
1991	4/20	4/24	5/01	5/14	5/28	6/04	7/09	28	1017	90	90.8	8.9
1992	4/12	4/14	4/16	4/30	5/11	5/21	6/02	26	1107	92	92.0	8.3
1993	4/17	4/21	4/24	5/07	5/18	5/19	6/02	25	1016	123	156.1	15.4
1994	4/20	4/21	4/22	5/06	5/26	6/03	6/07	35	733	71	87.4	11.9
1995	4/08	4/11	4/12	5/04	5/20	5/30	6/09	39	1008	112	142.0	14.1
1996	4/17	4/19	4/22	5/15	6/07	6/11	6/19	47	978	81	184.4	18.9
1997	4/09	4/12	4/17	4/28	5/16	5/20	5/21	30	527	43	93.0	17.6
1999	3/29	4/13	4/13	5/15	5/28	5/29	5/29	46	506	19	45.0	8.9

(1) Parr PIT-tagged and released during the summer of the year prior to detection year.
(2) PIT detections of yearling Age 1 chinook smolts at Lower Granite Dam.
(3) Spill-adjusted (Appendix C) PIT detections of yearling Age 1 chinook smolts at Lower Granite Dam.

Figure B11: Historical Marsh Creek outmigration distribution at Lower Granite Dam.

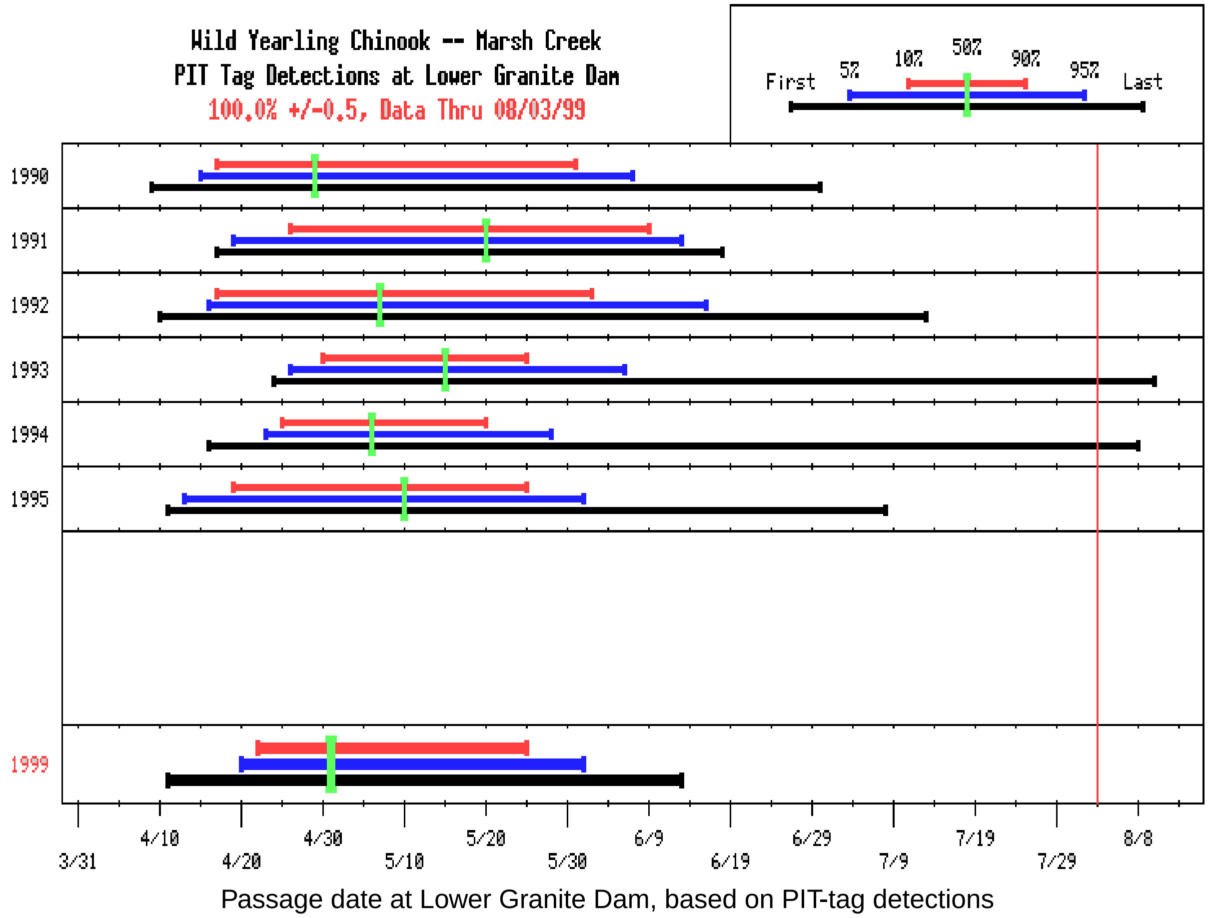
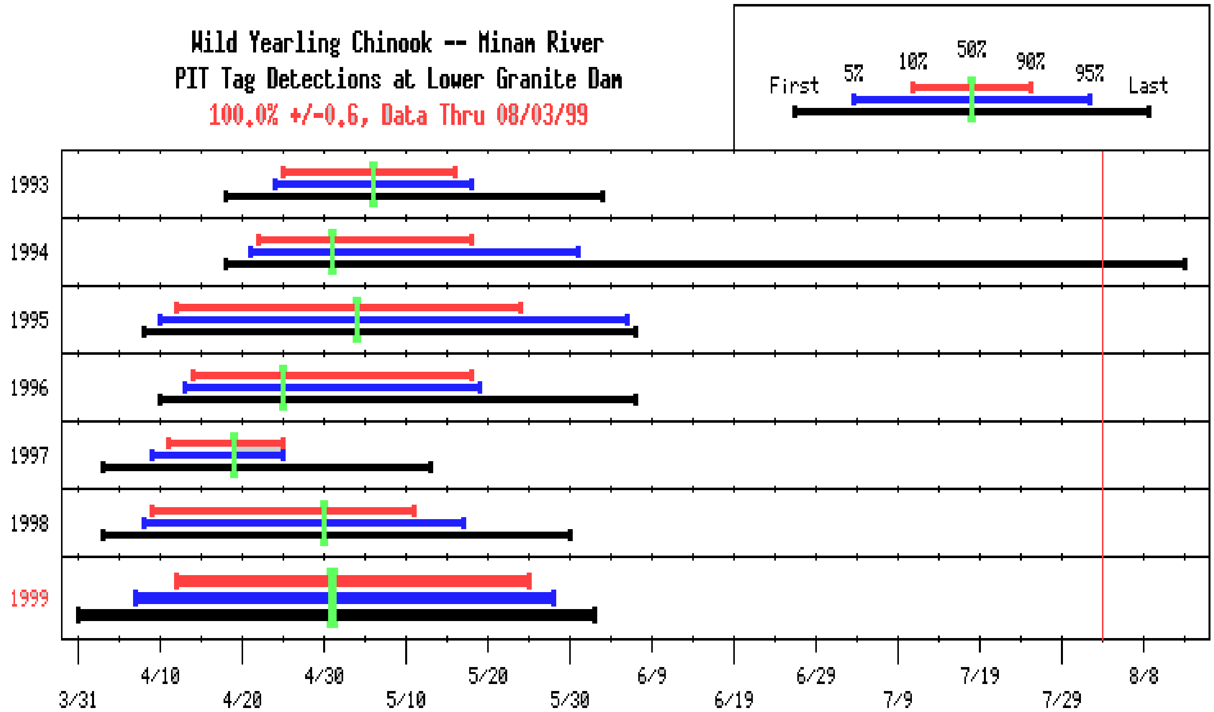


Table B11: Historical Marsh Creek outmigration timing characteristics.

Detection Year	Detection Dates							Duration Middle 80% (days)	Parr Released (1)	LGR PIT Detections (2)	Adjusted LGR PIT Detections (3)	% (3)/(1) x 100
	First	5%	10%	50%	90%	95%	Last					
1990	4/09	4/15	4/17	4/29	5/31	6/07	6/30	45	2517	179	179.0	7.1
1991	4/17	4/19	4/26	5/20	6/09	6/13	6/18	45	861	59	59.0	6.9
1992	4/10	4/16	4/17	5/07	6/02	6/16	7/13	47	981	67	67.0	6.8
1993	4/24	4/26	4/30	5/15	5/25	6/06	8/10	26	1000	82	126.5	12.6
1994	4/16	4/23	4/25	5/06	5/20	5/28	8/08	26	3690	507	609.8	16.5
1995	4/11	4/13	4/19	5/10	5/25	6/01	7/08	37	1590	103	142.7	9.0
1999	4/11	4/20	4/22	5/01	5/25	6/01	6/13	34	769	53	126.6	16.5

(1) Parr PIT-tagged and released during the summer of the year prior to detection year.
(2) PIT detections of yearling Age 1 chinook smolts at Lower Granite Dam.
(3) Spill-adjusted (Appendix C) PIT detections of yearling Age 1 chinook smolts at Lower Granite Dam.

Figure B12: Historical Minam River outmigration distribution at Lower Granite Dam.



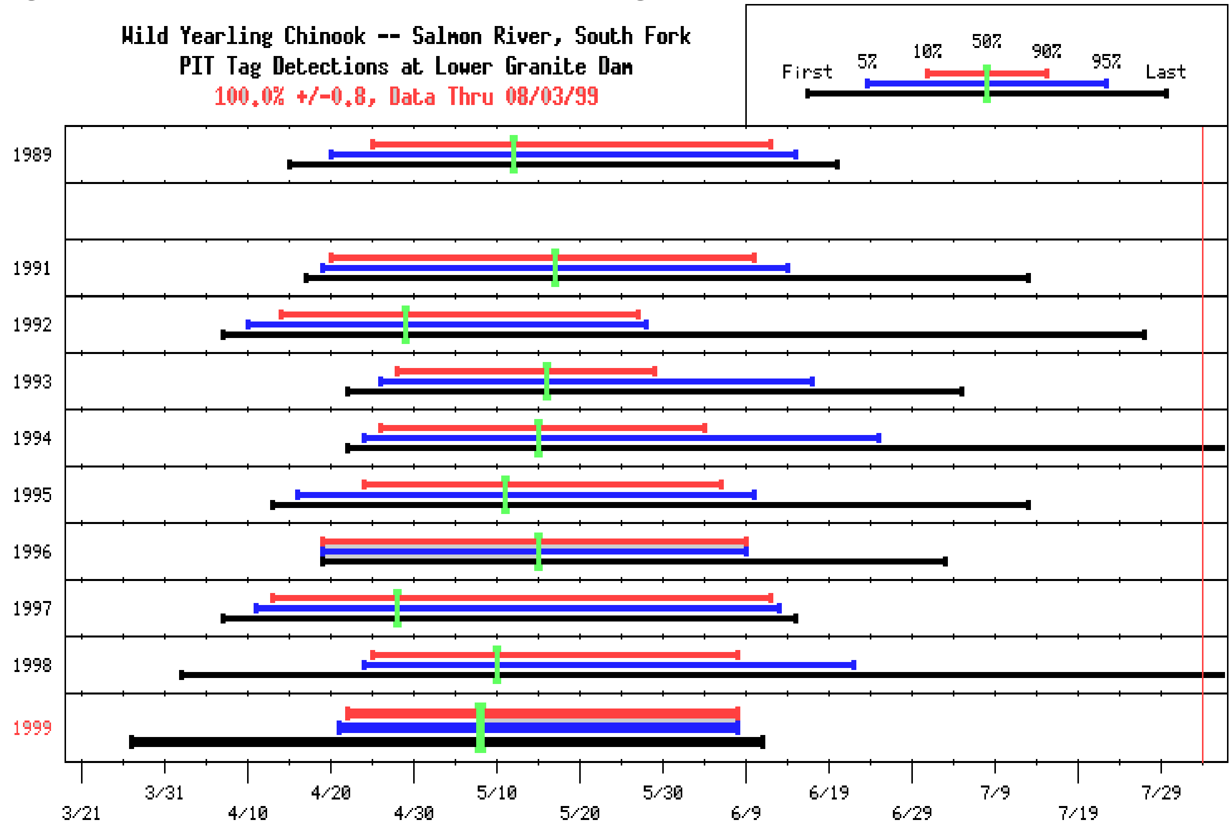
Passage date at Lower Granite Dam, based on PIT-tag detections

Table B12: Historical Minam River outmigration timing characteristics.

Detection Year	Detection Dates							Duration Middle 80% (days)	Parr Released (1)	LGR PIT Detections (2)	Adjusted LGR PIT Detections (3)	% (3)/(1) x 100
	First	5%	10%	50%	90%	95%	Last					
1993	4/18	4/24	4/25	5/6	5/16	5/18	6/3	22	1003	105	125.5	12.5
1994	4/18	4/21	4/22	5/1	5/18	5/31	8/13	27	1005	112	133.3	13.3
1995	4/8	4/10	4/12	5/4	5/24	6/6	6/7	43	998	70	89.3	8.9
1996	4/10	4/13	4/14	4/25	5/18	5/19	6/7	35	998	68	162.1	16.2
1997	4/03	4/09	4/11	4/19	4/25	4/25	5/13	15	589	49	92.4	15.7
1998	4/04	4/08	4/09	4/27	5/10	5/13	5/30	33	998	123	221.8	22.2
1999	3/31	4/07	4/12	5/01	5/25	5/28	6/02	44	1006	47	110.3	11.0

(1) Parr PIT-tagged and released during the summer of the year prior to detection year.
(2) PIT detections of yearling Age 1 chinook smolts at Lower Granite Dam.
(3) Spill-adjusted (Appendix C) PIT detections of yearling Age 1 chinook smolts at Lower Granite Dam.

Figure B13: Historical Salmon River, SF outmigration distribution at Lower Granite Dam.



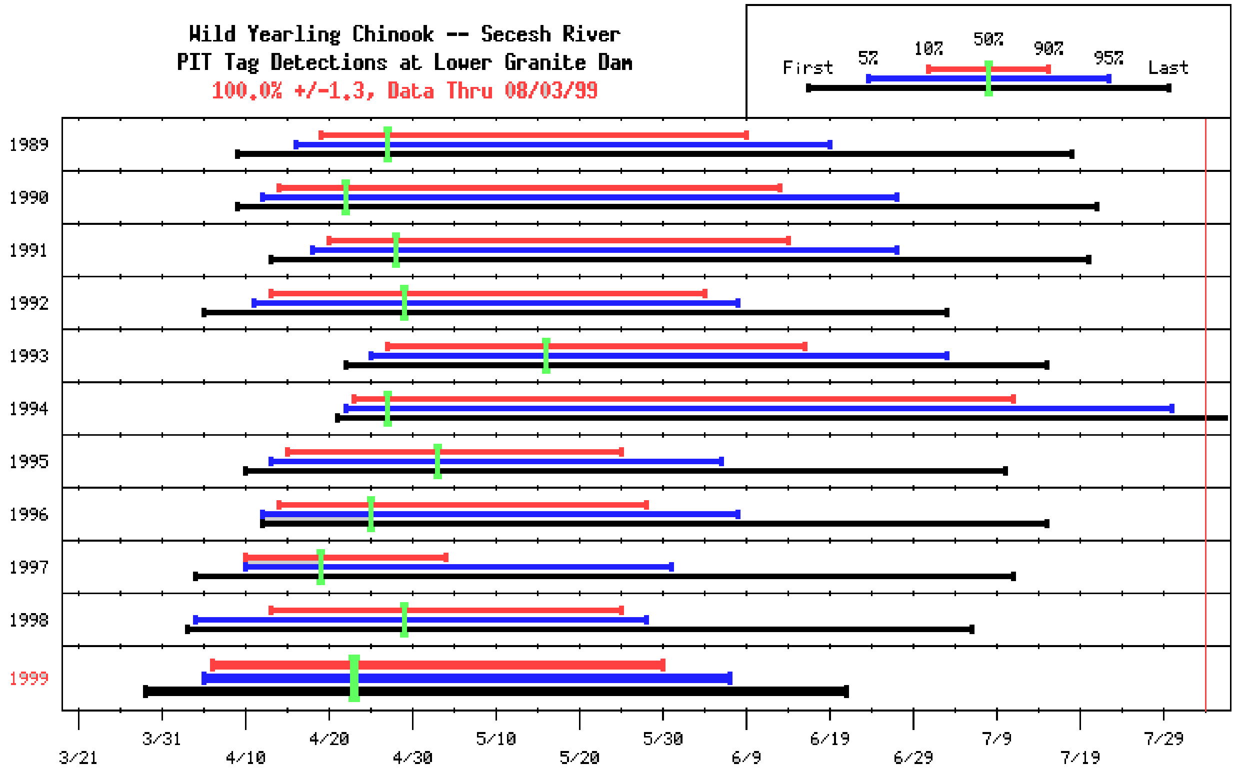
Passage date at Lower Granite Dam, based on PIT-tag detections

Table B13: Historical South Fork Salmon River outmigration timing characteristics.

Detection Year	Detection Dates							Duration Middle 80% (days)	Parr Released (1)	LGR PIT Detections (2)	Adjusted LGR PIT Detections (3)	% (3)/(1) x 100
	First	5%	10%	50%	90%	95%	Last					
1989	4/15	4/20	4/25	5/12	6/12	6/15	6/20	49	2226	84	84.0	3.8
1991	4/17	4/19	4/20	5/17	6/10	6/14	7/13	52	992	98	98.8	10.0
1992	4/7	4/10	4/14	4/29	5/27	5/28	7/27	44	1031	81	81.0	7.9
1993	4/22	4/26	4/28	5/16	5/29	6/17	7/5	32	1718	173	262.0	15.2
1994	4/22	4/24	4/26	5/15	6/4	6/25	8/9	40	5951	450	645.1	10.8
1995	4/13	4/16	4/24	5/11	6/10	6/10	7/13	44	1574	78	105.2	6.7
1996	4/19	4/19	4/19	5/15	6/9	6/9	7/3	52	700	16	37.2	5.3
1997	4/07	4/11	4/13	4/28	6/12	6/13	6/15	61	700	36	78.9	11.3
1998	4/02	4/22	4/24	5/10	6/23	7/08	8/07	45	1007	83	155.5	15.4
1999	3/27	4/21	4/22	5/08	6/08	6/08	6/11	48	998	38	87.6	8.8

(1) Parr PIT-tagged and released during the summer of the year prior to detection year.
(2) PIT detections of yearling Age 1 chinook smolts at Lower Granite Dam.
(3) Spill-adjusted (Appendix C) PIT detections of yearling Age 1 chinook smolts at Lower Granite Dam.

Figure B14: Historical Secesh River outmigration distribution at Lower Granite Dam.



Passage date at Lower Granite Dam, based on PIT-tag detections

Table B14: Historical Secesh River outmigration timing characteristics.

Detection Year	Detection Dates							Duration Middle 80% (days)	Parr Released (1)	LGR PIT Detections (2)	Adjusted LGR PIT Detections (3)	% (3)/(1) x 100
	First	5%	10%	50%	90%	95%	Last					
1989	4/09	4/16	4/19	4/27	6/09	6/19	7/18	52	1940	190	190.0	9.8
1990	4/09	4/12	4/14	4/22	6/13	6/27	7/21	61	2176	157	157.0	7.2
1991	4/13	4/18	4/20	4/28	6/14	6/27	7/20	56	1018	71	72.3	7.1
1992	4/05	4/11	4/13	4/29	6/04	6/08	7/03	53	1013	40	40.0	3.9
1993	4/22	4/25	4/27	5/16	6/16	7/03	7/15	51	327	30	37.0	11.3
1994	4/21	4/22	4/23	4/27	7/11	7/30	8/07	80	422	32	33.0	7.8
1995	4/10	4/13	4/15	5/03	5/25	6/06	7/10	41	1551	90	112.4	7.2
1996	4/12	4/12	4/14	4/25	5/28	6/08	7/15	45	571	26	70.0	12.3
1997	4/04	4/10	4/10	4/19	5/04	5/31	7/11	25	260	34	62.7	24.1
1998	4/03	4/04	4/13	4/24	5/19	6/02	7/06	43	588	74	126.1	21.4
1999	3/29	4/05	4/06	4/23	5/30	6/07	6/21	55	938	35	78.3	8.3

(1) Parr PIT-tagged and released during the summer of the year prior to detection year.
(2) PIT detections of yearling Age 1 chinook smolts at Lower Granite Dam.
(3) Spill-adjusted (Appendix C) PIT detections of yearling Age 1 chinook smolts at Lower Granite Dam.

Figure B15: Historical Sulfur Creek outmigration distribution at Lower Granite Dam.

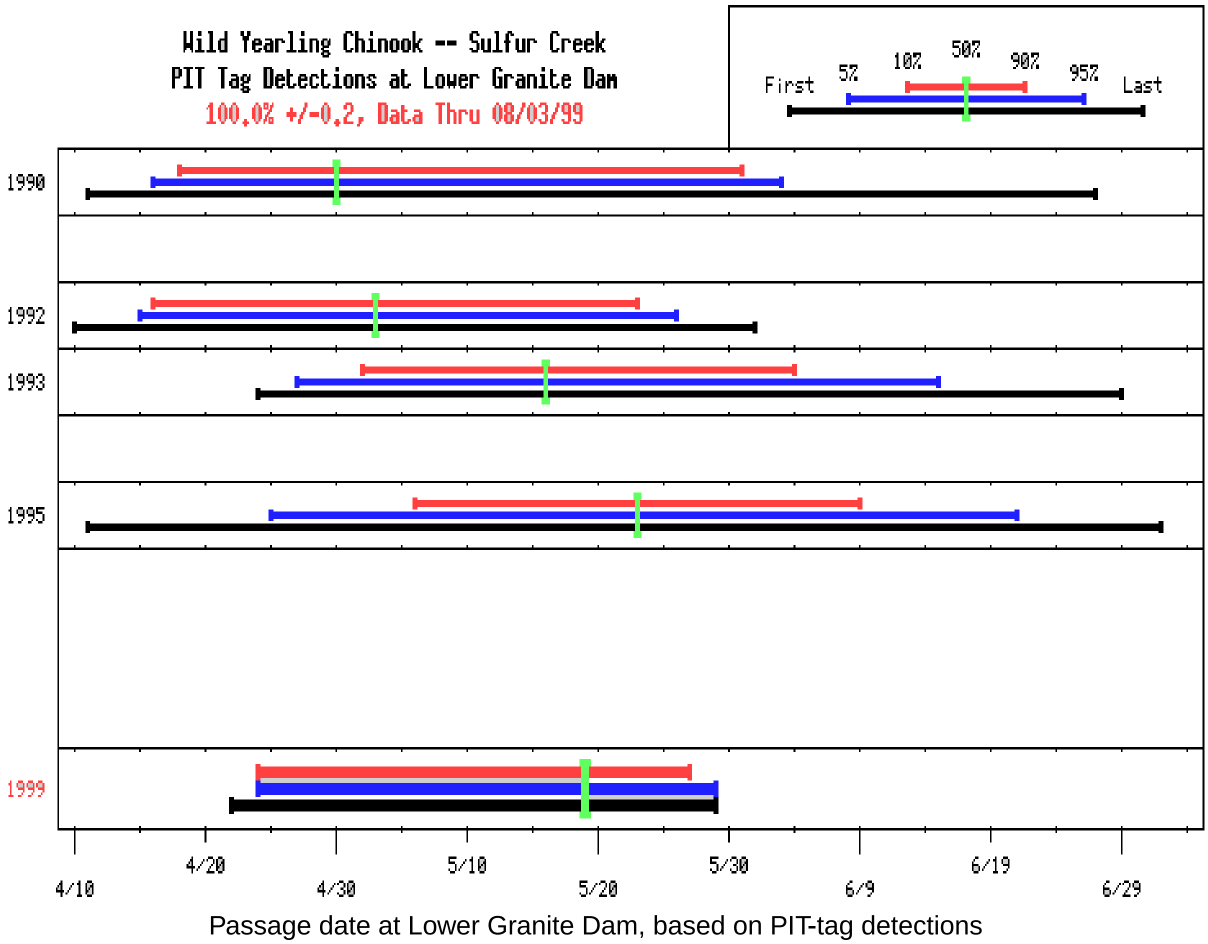


Table B15: Historical Sulfur Creek outmigration timing characteristics.

Detection Year	Detection Dates							Duration Middle 80% (days)	Parr Released (1)	LGR PIT Detections (2)	Adjusted LGR PIT Detections (3)	% (3)/(1) x 100
	First	5%	10%	50%	90%	95%	Last					
1990	4/11	4/16	4/18	4/30	5/31	6/03	6/27	44	2516	168	168.0	6.7
1992	4/10	4/15	4/16	5/03	5/23	5/26	6/01	38	210	24	24.0	11.4
1993	4/24	4/27	5/02	5/16	6/04	6/15	6/29	34	714	28	41.6	5.8
1995	4/11	4/25	5/06	5/23	6/09	6/21	7/02	35	728	56	80.2	11.0
1999	4/22	4/24	4/24	5/19	5/27	5/29	5/29	34	443	17	42.1	9.5

(1) Parr PIT-tagged and released during the summer of the year prior to detection year.
(2) PIT detections of yearling Age 1 chinook smolts at Lower Granite Dam.
(3) Spill-adjusted (Appendix C) PIT detections of yearling Age 1 chinook smolts at Lower Granite Dam.

Figure B16: Historical Valley Creek outmigration distribution at Lower Granite Dam.

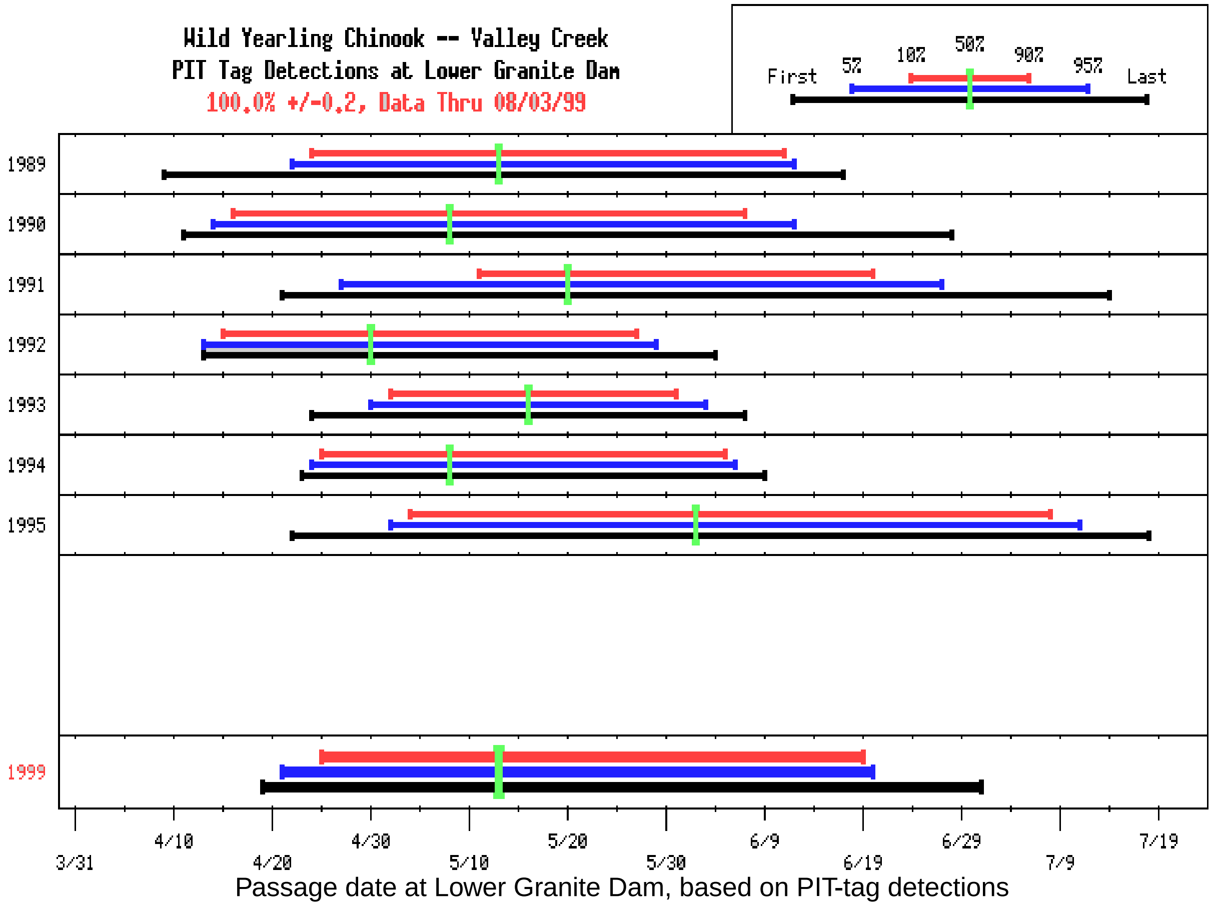


Table B16: Historical Valley Creek outmigration timing characteristics.

Detection Year	Detection Dates							Duration Middle 80% (days)	Parr Released (1)	LGR PIT Detections (2)	Adjusted LGR PIT Detections (3)	% (3)/(1) x 100
	First	5%	10%	50%	90%	95%	Last					
1989	4/09	4/22	4/24	5/13	6/11	6/12	6/17	49	1942	65	65.0	3.3
1990	4/11	4/14	4/16	5/08	6/07	6/12	6/28	53	2512	76	76.0	3.0
1991	4/21	4/27	5/11	5/20	6/20	6/27	7/14	41	1031	41	41.0	4.0
1992	4/13	4/13	4/15	4/30	5/27	5/29	6/04	43	969	34	34.0	3.5
1993	4/24	4/30	5/02	5/16	5/31	6/03	6/07	30	1028	32	51.2	5.0
1994	4/23	4/24	4/25	5/08	6/05	6/06	6/09	42	850	45	61.8	7.3
1995	4/22	5/02	5/04	6/02	7/08	7/11	7/18	66	1552	50	64.0	4.1
1999	4/19	4/21	4/25	5/13	6/19	6/20	7/01	56	1001	50	118.0	11.8

(1) Parr PIT-tagged and released during the summer of the year prior to detection year.
(2) PIT detections of yearling Age 1 chinook smolts at Lower Granite Dam.
(3) Spill-adjusted (Appendix C) PIT detections of yearling Age 1 chinook smolts at Lower Granite Dam.

Figure B17: Historical Redfish Lake outmigration distribution at Lower Granite Dam.

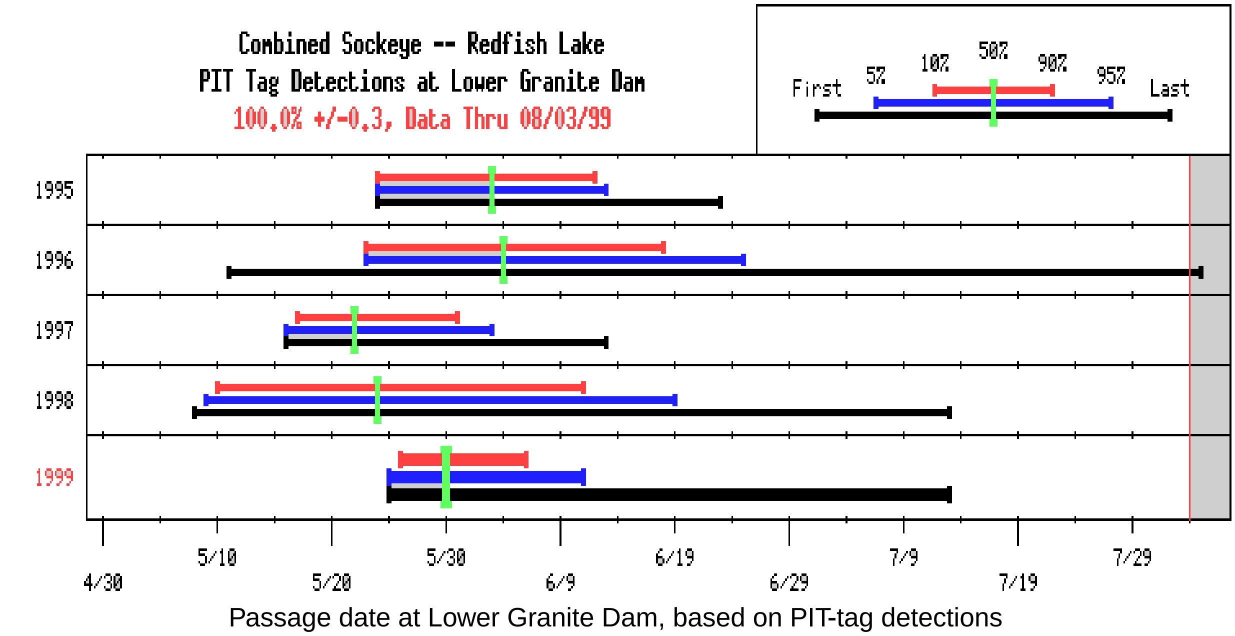


Table B17: Historical Redfish Lake outmigration timing characteristics.

Detection Year	Detection Dates							Duration Middle 80% (days)	Age 0+ Released (1)	LGR PIT Detections (2)	Adjusted LGR PIT Detections (3)	% (3)/(1) x 100
	First	5%	10%	50%	90%	95%	Last					
1995	5/24	5/24	5/24	6/03	6/12	6/13	6/23	20	2728	20	26.6	1.0
1996	5/11	5/23	5/23	6/04	6/18	6/25	8/04	27	4246	160	377.8	8.9
1997	5/16	5/16	5/17	5/22	5/31	6/03	6/13	15	1931	53	131.2	6.8
1998	5/08	5/09	5/10	5/24	6/11	6/14	7/13	33	4692	71	145.6	3.1
1999	5/25	5/25	5/26	5/30	6/06	6/11	7/13	12	4179	58	143.9	3.4

(1) Number of PIT-tagged Age 0+ juvenile sockeye released into Redfish Lake during the summer/fall of the year.
(2) Number of sockeye PIT detections at Lower Granite Dam
(3) Spill-adjusted number of PIT detections at Lower Granite Dam.

Figure B18: Historical Yearling Chinook Run-at-Large distribution at Lower Granite Dam.

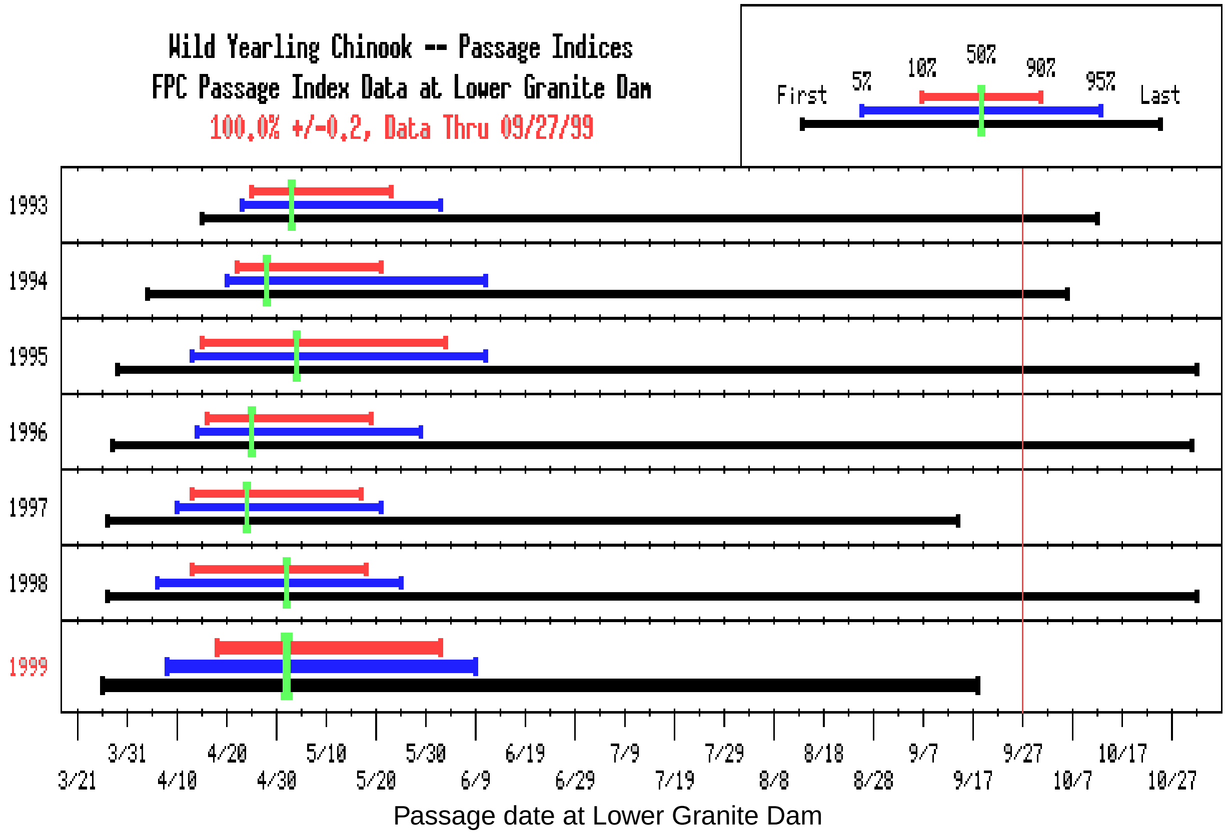


Table B18: Historical Wild Yearling Chinook Run-at-Large outmigration timing characteristics.

Detection Year	Passage Dates							Duration Middle 80% (days)	Total LGR Passage
	First	5%	10%	50%	90%	95%	Last		
1993	4/15	4/23	4/25	5/03	5/23	06/02	10/12	29	374138
1994	4/04	4/20	4/22	4/28	5/21	06/11	10/06	30	334022
1995	3/29	4/13	4/15	5/04	6/03	06/11	11/01	50	865290
1996	3/28	4/14	4/16	4/25	5/19	05/29	10/31	34	214106
1997	3/27	4/10	4/13	4/24	5/17	05/21	09/14	35	80861
1998	3/27	4/06	4/13	5/02	5/18	05/25	11/01	36	373736
1999	3/26	4/08	4/18	5/02	6/02	6/09	9/18	46	636314

Figure B19: Historical Steelhead Run-at-Large distribution at Lower Granite Dam.

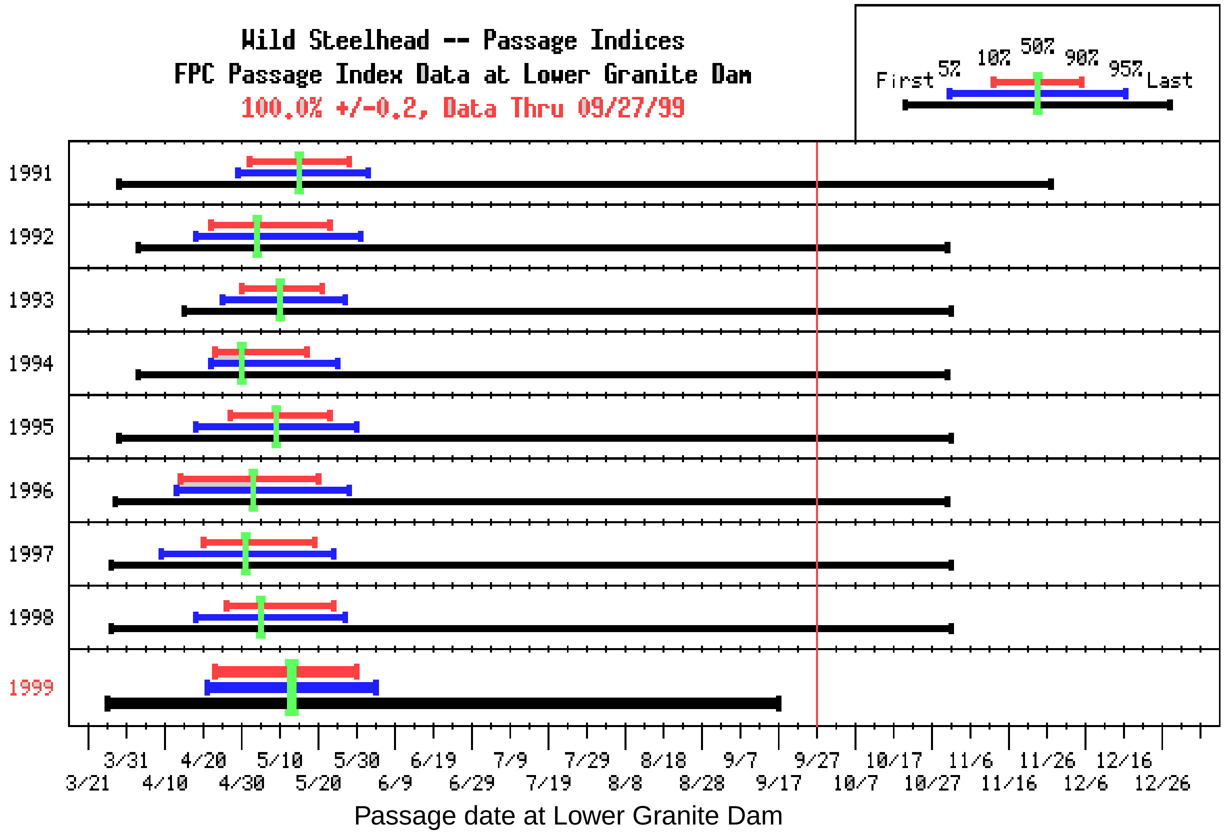


Table B19: Historical Wild Steelhead Run-at-Large outmigration timing characteristics.

Detection Year	Passage Dates							Duration Middle 80% (days)	Total LGR Passage
	First	5%	10%	50%	90%	95%	Last		
1991	3/29	4/29	5/02	5/15	5/28	6/02	11/27	27	628771
1992	4/03	4/18	4/22	5/04	5/23	5/31	10/31	32	583740
1993	4/15	4/25	4/30	5/10	5/21	5/27	11/01	22	576536
1994	4/03	4/22	4/23	4/30	5/17	05/25	10/31	25	517244
1995	3/29	4/18	4/27	5/09	5/23	5/30	11/01	27	485203
1996	3/28	4/13	4/14	5/03	5/20	5/28	10/31	37	525732
1997	3/27	4/09	4/20	5/01	5/19	5/24	11/01	30	435069
1998	3/27	4/18	4/26	5/05	5/24	5/27	11/01	29	754499
1999	3/26	4/21	4/23	5/13	5/30	6/04	09/17	38	502128

(**Figure B20: Historical PIT-tagged Subyearling Chinook Run-Timing at Lower Granite.**

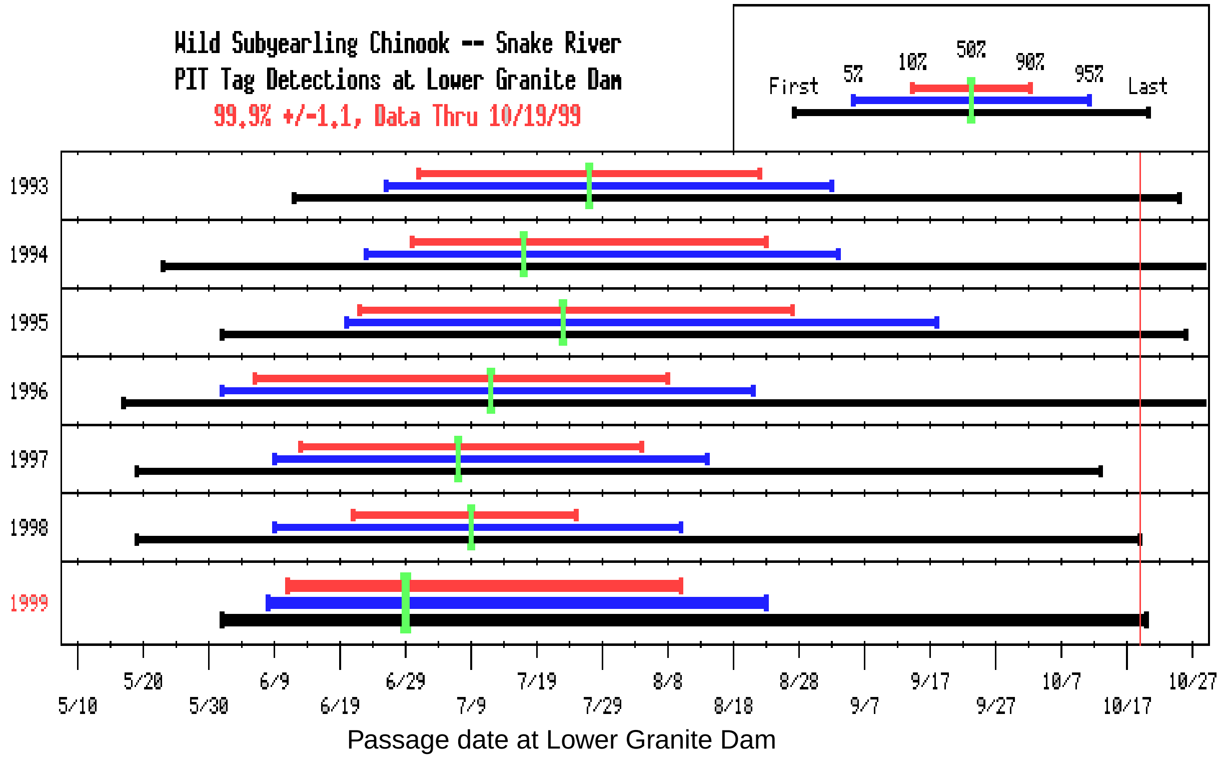


Table B20: Historical PIT-tagged Wild Subyearling Chinook outmigration timing characteristics.

Detection Year	Detection Dates							Duration Middle 80% (days)	Parr Released (1)	LGR PIT Detections (2)	Adjusted LGR PIT Detections (3)	% (3)/(1) x 100
	First	5%	10%	50%	90%	95%	Last					
1993	6/12	6/26	7/01	7/27	8/22	9/02	10/25	53	1099	172	172.1	15.7
1994	5/23	6/23	6/30	7/17	8/23	9/03	11/01	55	2342	193	199.1	8.5
1995	6/01	6/20	6/22	7/23	8/27	9/18	10/26	67	1374	440	454.0	33.0
1996	5/17	6/01	6/06	7/12	8/08	8/21	10/31	64	462	146	186.1	40.3
1997	5/19	6/09	6/13	7/07	8/04	8/14	10/13	53	641	124	164.3	25.6
1998	5/19	6/09	6/21	7/09	7/25	8/10	10/19	35	2054	549	676.1	32.9
1999	6/01	6/08	6/11	6/29	8/10	8/20	10/25	61	1760	592	835.5	47.5

(1) Smolts PIT-tagged and released during April through July of 1999 near the confluence of the Salmon and Snake Rivers, by William P. Connor (USFWS).
(2) PIT detections of fall subyearling Age 0 chinook smolts at Lower Granite Dam.
(3) Spill-adjusted (Appendix C) PIT detections of fall subyearling Age 0 chinook smolts at Lower Granite Dam.

Appendix C

Daily Expansion Factors for Spill-Adjusted PIT-Tagged Stocks Forecasted by Project RealTime in Migration Year 1999, including Wild Spring/Summer Yearling Chinook Salmon Fall Subyearling Chinook Salmon and Hatchery-reared Summer Sockeye Salmon Stocks

Table C1: Migration year 1999 “expansion factors” for spill-adjusting the RealTime project’s PIT-tagged stocks (Section 2.3). These factors are multiplied by the number of PIT-detections (“raw” smolt counts) each day at Lower Granite Dam. The resulting “adjusted counts” (e.g., Table 2) estimate the daily combined smolts detected in the PIT-detection system and smolts passing undetected through the spillway. (Factors are computed as 1/(1-SE), where SE is equal to spill effectiveness, defined in eqn. 1 of text).

Dates	Expansion Factors	Dates	Expansion Factors	Dates	Expansion Factors	Dates	Expansion Factors
01/01	1.00	01/25	1.00	02/19	1.00	03/16	1.00
01/02	1.00	01/26	1.00	02/20	1.00	03/17	1.00
01/03	1.00	01/27	1.00	02/21	1.00	03/18	1.00
01/04	1.00	01/28	1.00	02/22	1.01	03/19	1.00
01/05	1.00	01/29	1.00	02/23	1.00	03/20	1.00
01/06	1.00	01/30	1.00	02/24	1.02	03/21	1.04
01/07	1.00	01/31	1.00	02/25	1.00	03/22	1.77
01/08	1.00	02/01	1.00	02/26	1.00	03/23	1.79
01/09	1.00	02/02	1.00	02/27	1.00	03/24	1.10
01/10	1.00	02/03	1.00	02/28	1.00	03/25	1.48
01/11	1.00	02/04	1.00	03/01	1.00	03/26	1.44
01/12	1.00	02/05	1.00	03/02	1.00	03/27	2.22
01/13	1.00	02/06	1.00	03/03	1.00	03/28	2.02
01/14	1.00	02/07	1.00	03/04	1.00	03/29	1.04
01/15	1.00	02/08	1.00	03/05	1.00	03/30	1.02
01/16	1.00	02/09	1.00	03/06	1.00	03/31	1.00
01/17	1.00	02/10	1.00	03/07	1.00	04/01	1.00
01/18	1.00	02/11	1.00	03/08	1.00	04/02	1.50
01/19	1.00	02/12	1.00	03/09	1.00	04/03	2.16
01/20	1.00	02/13	1.00	03/10	1.00	04/04	2.20
01/21	1.00	02/14	1.00	03/11	1.00	04/05	2.55
01/22	1.00	02/15	1.00	03/12	1.00	04/06	2.56
01/23	1.00	02/16	1.00	03/13	1.00	04/07	2.74
01/24	1.00	02/17	1.00	03/14	1.00	04/08	2.82

Table C1: Migration year 1999 "expansion factors" for spill-adjusting the RealTime project's PIT-tagged stocks (Section 2.3). These factors are multiplied by the number of PIT-detections ("raw" smolt counts) each day at Lower Granite Dam. The resulting "adjusted counts" (e.g., Table 2) estimate the daily combined smolts detected in the PIT-detection system and smolts passing undetected through the spillway. (Factors are computed as 1/(1-SE), where SE is equal to spill effectiveness, defined in eqn. 1 of text).

Dates	Expansion Factors	Dates	Expansion Factors	Dates	Expansion Factors	Dates	Expansion Factors
04/10	2.82	05/06	2.38	06/01	2.56		
04/11	2.97	05/07	2.50	06/02	2.65	06/27	1.94
04/12	2.94	05/08	2.42	06/03	2.49	06/28	1.76
04/13	2.86	05/09	2.48	06/04	2.56	06/29	1.34
04/14	2.80	05/10	2.36	06/05	2.48	06/30	1.32
04/15	2.85	05/11	2.52	06/06	2.36	07/01	1.24
04/16	2.75	05/12	2.66	06/07	2.22	07/02	1.06
04/17	2.72	05/13	2.67	06/08	2.81	07/03	1.00
04/18	2.56	05/14	2.68	06/09	2.26	07/04	1.00
04/19	2.33	05/15	2.76	06/10	2.17	07/05	1.00
04/20	2.03	05/16	2.88	06/11	2.09	07/06	1.00
04/21	1.92	05/17	2.78	06/12	2.26	07/07	1.00
04/22	1.95	05/18	2.77	06/13	2.14	07/08	1.00
04/23	2.02	05/19	2.61	06/14	2.13	07/09	1.00
04/24	2.27	05/20	2.61	06/15	2.18	07/10	1.00
04/25	2.98	05/21	2.46	06/16	2.37	07/11	1.00
04/26	2.61	05/22	2.58	06/17	2.41	07/12	1.00
04/27	2.61	05/23	2.13	06/18	2.51	07/13	1.00
04/28	2.57	05/24	2.22	06/19	2.55	07/14	1.00
04/29	2.19	05/25	2.43	06/20	2.50	07/15	1.00
04/30	2.29	05/26	2.82	06/21	2.24	07/16	1.00
05/01	2.36	05/27	2.91	06/22	2.34	07/17	1.00
05/02	2.30	05/28	2.44	06/23	2.34	07/18	1.00
05/03	2.28	05/29	2.45	06/24	2.41	07/19	1.03
05/04	2.18	05/30	2.72	06/25	2.25	07/20	1.00
05/05	2.31	05/31	2.62	06/26	2.47	07/21	1.00

Table C1: Migration year 1999 "expansion factors" for spill-adjusting the RealTime project's PIT-tagged stocks (Section 2.3). These factors are multiplied by the number of PIT-detections ("raw" smolt counts) each day at Lower Granite Dam. The resulting "adjusted counts" (e.g., Table 2) estimate the daily combined smolts detected in the PIT-detection system and smolts passing undetected through the spillway. (Factors are computed as 1/(1-SE), where SE is equal to spill effectiveness, defined in eqn. 1 of text).

Dates	Expansion Factors	Dates	Expansion Factors	Dates	Expansion Factors	Dates	Expansion Factors
07/22	1.00	08/17	1.03	09/12	1.00	10/08	1.00
07/23	1.00	08/18	1.10	09/13	1.00	10/09	1.00
07/24	1.00	08/19	1.00	09/14	1.00	10/10	1.00
07/25	1.00	08/20	1.00	09/15	1.00	10/11	1.00
07/26	1.00	08/21	1.00	09/16	1.00	10/12	1.00
07/27	1.00	08/22	1.00	09/17	1.00	10/13	1.00
07/28	1.00	08/23	1.00	09/18	1.00	10/14	1.00
07/29	1.00	08/24	1.00	09/19	1.00	10/15	1.00
07/30	1.00	08/25	1.00	09/20	1.00	10/16	1.00
07/31	1.00	08/26	1.00	09/21	1.00	10/17	1.00
08/01	1.00	08/27	1.00	09/22	1.00	10/18	1.00
08/02	1.00	08/28	1.00	09/23	1.00	10/19	1.00
08/03	1.02	08/29	1.00	09/24	1.00	10/20	1.00
08/04	1.00	08/30	1.00	09/25	1.00	10/21	1.00
08/05	1.01	08/31	1.00	09/26	1.00	10/22	1.00
08/06	1.00	09/01	1.00	09/27	1.00	10/23	1.00
08/07	1.03	09/02	1.00	09/28	1.00	10/24	1.00
08/08	1.00	09/03	1.00	09/29	1.00	10/25	1.00
08/09	1.01	09/04	1.00	09/30	1.00	10/26	1.00
08/10	1.09	09/05	1.00	10/01	1.00	10/27	1.00
08/11	1.05	09/06	1.00	10/02	1.00	10/28	1.00
08/12	1.10	09/07	1.00	10/03	1.00	10/29	1.00
08/13	1.06	09/08	1.00	10/04	1.00	10/30	1.00
08/14	1.04	09/09	1.00	10/05	1.00	10/31	1.09
08/15	1.07	09/10	1.00	10/06	1.00	11/01	1.00
08/16	1.03	09/11	1.00	10/07	1.00	11/02	2.07

Table C1: Migration year 1999 “expansion factors” for spill-adjusting the RealTime project’s PIT-tagged stocks (Section 2.3). These factors are multiplied by the number of PIT-detections (“raw” smolt counts) each day at Lower Granite Dam. The resulting “adjusted counts” (e.g., Table 2) estimate the daily combined smolts detected in the PIT-detection system and smolts passing undetected through the spillway. (Factors are computed as 1/(1-SE), where SE is equal to spill effectiveness, defined in eqn. 1 of text).

Dates	Expansion Factors	Dates	Expansion Factors	Dates	Expansion Factors
11/03	1.00	11/28	1.00	12/23	1.00
11/04	1.00	11/29	1.00	12/24	1.00
11/05	1.00	11/30	1.00	12/25	1.00
11/06	1.00	12/01	1.00	12/26	1.00
11/07	1.00	12/02	1.00	12/27	1.00
11/08	1.00	12/03	1.00	12/28	1.00
11/09	1.00	12/04	1.00	12/29	1.00
11/10	1.00	12/05	1.00	12/30	1.00
11/11	1.00	12/06	1.00	12/31	1.00
11/12	1.00	12/07	1.00		
11/13	1.00	12/08	1.00		
11/14	1.00	12/09	1.00		
11/15	1.00	12/10	1.00		
11/16	1.00	12/11	1.00		
11/17	1.00	12/12	1.00		
11/18	1.00	12/13	1.00		
11/19	1.00	12/14	1.00		
11/20	1.00	12/15	1.00		
11/21	1.00	12/16	1.00		
11/22	1.00	12/17	1.00		
11/23	1.00	12/18	1.00		
11/24	1.00	12/19	1.00		
11/25	1.00	12/20	1.00		
11/26	1.00	12/21	1.00		
11/27	1.00	12/22	1.00		